IDENTIFICATION, DISTRIBUTION AND CONTROL OF THREE SMUTS OF SPRING BARLEY

by

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TABLE OF CONTENTS

INTRODUCTION

The smuts of our cereal crops take a staggering toll each year. Some of this loss goes unnoticed by the farmer and that which is noticed in many cases is just taken for granted as in many instances it is something against which he feels there is no practical control. Although barley is not a major crop in Kansas, where it is grown it likewise has its share of smut. With the present control measures for Ustilago hordei (Pers.) Lagerh. and Ustilago nigra Tapke, there is no excusable reason for having any appreciable loss due to these two fungi, but so far there is no truly practical control measure for Ustilago nuda (Jens.) Rostr. that the individual farmer can employ. The modified hot-water treatment is the only known method of control of this smut and it is so exacting in its application that it is difficult for the ordinary farmer to use, and in addition it often is injurious to the host plant.

Since there has not been much research done with this treatment as to its effect on the germination of the barley seed, it is my purpose to endeavor to show why there is such a wide variation in the injurious effects of this treatment on the various barley varieties. If being unable to attribute this variation to a definite factor or factors, being able, at least, to prove that it is not due to certain other factors; and keeping uppermost the thought of the urgent need for a more practical means of control and hoping that in some way this work may be of value in reaching a practical control measure that will not in itself reduce the germination or otherwise be injurious to the barley seed.

Inasmuch as only a limited amount of literature has been published on research of a similar nature to that reported in this paper, the writer has chosen to review additional related literature which might aid in interpreting data reported here.

REVIEW OF THE LITERATURE

The barley smuts have been described and classified in many different ways, but the original description as given by Kellerman and Swingle (1889) follows in part. This is not entirely devoted to description of the barley smuts, but the other information given by them seemed worthy of retaining.

> The loose smuts are four closely allied species found on oats, wheat, and barley. Wheat is sometimes attacked by other smuts, which are, however, quite different. All the loose smuts are, as their name indicates, of a powdery nature. All attack the heads or panicles of the cereal, and usually destroy them more or less completely. They are not confined to the grain, as is the case of stinking smut of wheat. The black powdery mass consists of the reproductive bodies called spores, which correspond in function to the seeds of the common plants. The vegetative portion of the parasitic fungus is wholly concealed within the tissue of the plant that is attacked. It does not cause immediate death, nor marked abnormal growth. Its presence is not easily recognized until it begins the production of its spores, forming the conspicuous black mass where the grains should have been formed.
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> All of the four species described are so nearly alike, that until a few years ago they were considered but one species, to which the name Ustilago segetum (Bull.) Ditt, or U. carbo (DC.) Tul., was applied. It has recently been shown by Jenson that the smut of oats, wheat and barley were unable to infect any of the cereals except that on which they grew. We have found a considerable difference in the manner of germination in these species, making it doubly certain that these forms are really distinct species. The importance of this fact is obvious: farmers need not fear that their oats will become infected from neighboring wheat or barley fields, and vice-versa.

The life-history of these smuts is, as far as known, as follows: The loose spores are blown about by the wind, (or during the threshing,) and attach themselves to the grains. In the case of oats and barley, only those spores which are inside the husks are able to infect the plants to any appreciable extent. The smut being ripe during the flowering-time, the spores blown about by the wind fall upon the young grains, and are inclosed with in by the husks.

When the seed is planted, in spring, the spores of the smut germinate and send out minute germ threads, which enter the young plant only through the first delicate leaf sheath. Only for a few days is the smut able to enter this leaf, and after the second leaf breaks through this sheath the plants are free from further infection. Assuming that the minute germ threads of the smut did enter the sheathing leaf at the proper time, the fungus develops as follows: The minute thread entering the sheathing leaf penetrates to all the parts of the stem and branches; its growth keeps pace with that of the host plant, until, at length, just before the time of flowering, the fungus forms a mass of thick threads in the young forming head, and inside of these threads the spores are produced. As the spores grow, the threads become gelatinous, and finally, when the spores are ripe, they disappear entirely, leaving a loose mass of spores.

This is essentially the course of development in all the species, though the manner of infection may vary somewhat from that here described, especially in case of the loose smuts of wheat and barley.

The following key shows in brief the characters of the different loose smuts:

1. Spores smooth, 2.
1. Spores minutely spiny, or warty, 3.
   2. Spores dark brownish in mass, contents often granular. Ustilago avenae Var. levis.
   2. Spores black in mass, contents not granular. Ustilago hordei.
3. Producing sporidia readily. Ustilago avenae.
3. Not producing sporidia readily, if at all, 4.
   4. Promycelia long, very much branched in nutrient solution; ends, however, not swollen. Ustilago tritici.
   4. Promycelia shorter, sparingly branched or simple, ends of branches very often becoming swollen. Ustilago nuda.

The description of the barley smuts as given by Kellerman and Swingle (1889) are as follows:

Ustilago hordei. Covered smut of barley.
Spores in mass perfectly black, constant in size, globose or subglobose; epispore perfectly smooth. Promycelia in nutrient solution little or much branched, producing countless sporules, but not commonly germ threads; producing in water sporules but very few germ threads. Spores in mass somewhat firm.

Ustilago nuda. Naked smut of barley.
Spores in mass dark brownish, with an olivaceous shade, rather constant, oval or less often elliptical or subglobose. Promycelia in nutrient solution not very much branched, never producing sporules, branches often swollen at tips; in water producing no sporidia, but many germ threads.

The following information and description of the barley smuts is given for the historical value and to indicate the progress that has been made in the studies of the barley smuts, even though the present authorities do not entirely agree with the facts given herein.

The first writer to separate the smut of barley from that of oats according to Kellerman and Swingle (1889) was Lobelius, who, in 1591, referred to the forms on barley as Ustilago polystichi and U. hordei distychi. There is no way of knowing whether he included one or both of the barley smuts under these names. Bauhin, in 1596, also separated barley from oats smut, calling the former Ustilago hordeacea; nothing further is known of this. Other writers included this with the other loose smuts till Tessier, according to Persoon, Kellerman and Swingle (1889), noticed this smut; but Persoon, in 1801, was the first to give a recognizable description of it. He called it Uredo (Ustilago) segetum a uredo hordei, "pseudoperidio subelliptico, regulose, pulvere latente;" or, spore cases sub-elliptical, slightly wrinkled, powder hiding. This reference to the powder as latente (hiding) would seem to make it certain that he had the covered barley smut. After Persoon, many writers

copied his varietal names, without adding anything. Tulasne in 1847, Kellerman and Swingle (1889), called the smut of barley Ustilago carbo a vulgaris c hordeacea. Jensen in 1888, Kellerman and Swingle (1889), was the first writer to clearly separate this form from the other on barley, under the name Ustilago segetum var. tecta, and also Ustilago segetum var. hordei tecta. In Le charbon des cereales, published in 1889, he calls it Ustilago hordei var. tecta (Jensen). In a recent letter he recognizes it as a species, calling it Ustilago tecta hordei Jensen. The law of priority, however, compels the use of the earliest name, so the principal synonomy for U. hordei will be as given below. It is, however, nearly all doubtful, since almost all the writers confused U. hordei with U. nuda.

1552 Ustilago tragus, De Stirp.

1591 Ustilago polystichi Lobelius.

1591 Ustilago hordei distychi Lobelius.

1596 Ustilago hordeacea C. Bauhin.

1767 Chaos Ustilago Linne.

1791 (?) Reticularia Ustilago Linne.

1791 Reticularia segetum Bulliard.

1801 Uredo (Ustilago) segetum a uredo hordei Persoon.

1809 Caeoma segetum Link.

1813 Ustilago segetum (Bulliard) Dittmar.

1815 Uredo carbo a hordei DeCandolle.

1833 Erysibe vera a hordei Wallroth.

1837 Uredo carbo-hordei Philippar Traite.

1847 Ustilago carbo a vulgaris c hordeacea L.R. et Ch. Tulasne.

1856 (?) Ustilago segetum b hordei Rabenhorst.

1888 Ustilago segetum var. hordei f. tecta. Jensen.

1888 Ustilago segetum var. tecta Jensen.

1888 Ustilago hordei (Rabenhorst) Lagerheim.

1888 Ustilago segetum var. hordei tecta Jensen.

1889 Ustilago hordei v. tecta Jensen.

1890 Ustilago tecta hordei Jensen.

The covered barley smut as to nature of injuries to the host plant differs from all the other loose smuts in that the attacked head is not at once converted into a powdery mass by the escape of the smut, but the smut remains more or less completely enclosed by a membrane. This membrane consists of the outer-surface tissue of the attacked glumes, lemmas, paleas, etc., of the diseased flower. It is not, as in case of the stinking smut of wheat, simply the outer coat of the transformed seed, but a membrane composed of the outer layer of the many firmly united floral parts. It is usually confined to the bases of these parts, and consequently the awns are sometimes as long as in normal spikelets. Sometimes, however, they are much stunted, and often some of the smaller floral parts are smutted to the extreme tip. The membrane surrounding this smut is not nearly as fragile as in case of the loose barley smut or the loose smut of wheat and oats. It keeps the smut intact for some time, and finally allows it to escape through rents and fissures in the membrane. The inside of the diseased spikelets is by no means a simple powdery mass of spores. In every specimen examined, the interior of these diseased spikelets was occupied more or less by thin plates and shreds of unsmutted tissue. These plates and shreds are variously

connected, and in some cases are so firm that a section can be easily cut through the whole spikelet without previous preparation of any kind. The spores themselves do not readily fall to powder, and seem rather firmly glued together. This somewhat rigid strengthening of the smutted spikelet and firm mass of spores prevent very effectively their rapid escape.

The smut is readily characterized by the dark color of its spores when compared with the loose smut of barley. The spores in mass seem perfectly black; rarely, in some specimens, the color is a very dark brown. It never has any shade of olivaceous, and seems more like U. avenae than U. nuda or U. tritici in color. It is, however, always darker than oats smut.

In shape, the spores of this species are well marked. They are almost exactly spherical, and only rarely approach the oval form so common in the other three species. The spores are, however, often very slightly angular; rarely they have a small outgrowth and still more rarely the spores are double. In size the spores vary less; they are 5-8 x 5-7 microns (mostly 6-8 x 6-7 microns), being appreciably larger than those of Ustilago nuda.

The spore wall is as in other species composed of two layers, the epispore and endospore. They are not well defined and often the line between them cannot be seen at all. The compared thickness of the two layers is from 1 micron to 2 microns, or rarely somewhat more.

As in the other species, one side of the spore is darker, and often has a thicker epispore. The coloration is peculiar in that it is often very dark over the greater portion of the spore, and quite light in one

area. In many instances there are two such light areas; in this case one is always larger and lighter than the other. The spore appears to have dark sides, and a dark band across the middle.

The epispore of this species is different from those of the other three species in being always perfectly smooth. This character alone is sufficient to distinguish at a glance the two barley smuts, since Ustilago nuda has a spiny epispore.

The spores do not seem to separate into a powder as readily as do those of the other loose smuts under consideration, and in some cases constitute a somewhat firm mass inside the diseased spikelet. This again hinders the escape of the spores.

With reagents the spores behave much as those of Ustilago nuda, U. tritici and U. avenae. Chromic acid soon dissolves them, beginning at the lightest side. Nitric acid causes them to swell and become lighter colored. In chloriodide of zinc the wall becomes somewhat decolorized.

In germinating this smut in water, the spores after remaining a few hours in water, sent out one, or rarely two, blunt hyaline tubes from the lightest-colored portion. When two tubes were sent out they usually arose from opposite light areas of the spore. At first this tube was narrow (usually about 2-3 microns) and short; it, however, rapidly elongated, and became thicker either close to the spore or gradually--in the latter case the promycelium became club-shaped. The ends often became pointed where they produced sporules. By 24 hours, nearly every spore had germinated, and the promycelia had attained a length of 15-40 microns or even as much as 50 microns when exceptionally slender or when the promycelium became septate, either once or twice in most cases. Many

sporidia had been formed, both from the sides of the promycelium usually just below a septum, and also in many cases from the tip. These sporidia were rather abundant, but fell off almost as soon as formed, although in rare instances they remained attached while they themselves budded, producing secondary sporidia of about the same size. The sporidia were narrow, cylindrical to sub-oval in shape, usually about 5.5-7 x 2-3 microns, very rarely as much as 12 microns long, being more regular in size and shape and smaller (especially narrower) than the sporidia produced in nutrient solution. The detached sporidia often budded, producing a secondary sporidium of about equal size.

After remaining three or four days in water, at a temperature of 23° or 27° C., all growth ceased, and the culture remained dormant until the water evaporated, or it was invaded with bacteria which gradually increased until they destroyed it.

The first stages of germination in nutrient solution are very similar to those in water. Promycelia are sent out from the pale side of the spore, or, rarely, from two pale areas, and are at first short and simple. Soon they become septate, the division wall nearest the tip appearing first, and finally one or two nearer the base. About this time sporidia begin to be produced from the end of the promycelia, and also from their sides at the septa. These sporidia are much like those produced in water-cultures, but are slightly wider and larger, and much more abundant. After 24 hours nearly every spore has germinated, and the promycelia are about as long as they ever become when grown in water. They differ from those grown in water-cultures in being thicker and more vigorous. Up to this point, the cultures in nutrient solution were much

like those in water, the difference being that the promycelia were more vigorous, wider, and the sporules more abundant and budding more profusely. Instead of now growing less and less, and finally ceasing growth and becoming dormant, as the water-cultures do after two to four days, the growth in nutrient solution increased in vigor until the nourishment begins to fail.

In germinations either in water or in nutrient solution, the exact course of the promycelium through the wall was hard to trace; it was, however, apparently at first always a small round hole, from the inside of the spore. Thus it would seem that there is a definite pore in the light portion of the space rather than a rent, or perhaps the growing promycelia dissolves the cell-wall.

In the manner of infection of the host plant Jensen says according to Kellerman and Swingle (1889), spores of covered smut "adhering externally to the barley kernels will propagate the smut. In this respect it is different from all the other loose smuts, and resembles the stinking smut of wheat." It is, however, much less infectious. It spreads only slowly to adjacent fields, because the spores, being somewhat enclosed, are not as readily blown about by the wind.

According to Jensen, Kellerman and Swingle (1889), the loose smut is readily killed, either by treating the seed with copper sulphate or in hot water. It is, however, necessary to notice that this species is capable of infecting grains of barley to which it adheres, and hence the treated barley must be carefully protected from all contact with the smut. Until very recently the naked barley smut has been confused with the covered barley smut, or at any rate not carefully separated from it.

Its early history is therefore the same as already given for Ustilago hordei.

According to J. P. Petersen, Rostrup, Kellerman and Swingle (1889), in commenting on a paper by Jensen, communicated that in his germinating experiments there was a very material difference between the two kinds of barley smut: the covered barley smut develops sporidia, whereas the naked barley smut, in contradistinction from all other known forms of smut does not form sporidia, and therefore grows directly into the germinating plants.

The following synonomy of U. nuda includes nearly all the names applied to barley smut, but since Ustilago nuda has been constantly confused with Ustilago hordei it is somewhat doubtful:

1652 Ustilago tragus, De stirp.

1591 Ustilago polystichi Lobelius.

1591 Ustilago hordei distychi Lobelius.

1596 Ustilago hordeacea C. Bauhin.

1767 Chaos Ustilago Linne.

1791 (?) Reticularia Ustilago Linne.

1791 Reticularia segetum Bulliard.

1809 Caeoma segetum Link.

1813 Ustilago segetum (Bulliard) Dittmar.

1815 Uredo carbo a hordei DeCandolle.

1833 Erysibe vera a hordei Wallroth.

1837 Uredo carbo-hordei Philippar.

1847 Ustilago carbo a vulgaris o hordeacea L.R. et Ch.Tulasne.

1856 (?) Ustilago segetum b hordei Rabenhorst.

1888 Ustilago hordei Brefeld.

1888 Ustilago segetum var. hordei f nuda Jensen.

1888 Ustilago segetum var. nuda Jensen.

1888 Ustilago segetum var. hordei nuda Jensen.

1888 Ustilago hordei (Rabenhorst) Lagerheim.

1889 Ustilago hordei v. nuda Jensen.

1890 Ustilago nuda hordei Jensen.

In its injuries to the host plant the naked barley smut resembles oat smut and loose smut of wheat in that the attacked heads are converted into a loose, powdery mass of spores, held together only by a few shreds of tissue, and readily blown about by the wind. It differs very materially from the covered barley smut in this particular. It is, like that species, covered with a membrane which, however, is much thinner than in U. hordei, and consists apparently of the outer walls of the modified epidermal cells. Usually all, or nearly all of the floral parts are converted into the smut, only rarely being like U. hordei in having the tips of the floral parts sound. The awns are quite often intact, but are almost always stunted. The coalesced floral parts, while yet covered by their membrane, are of a dark, dull-grayish color much darker than U. hordei. The envelope ruptures very easily in any direction, and allows the loose spores to fall out. Through the spore masses run some plates or ribbons of host tissue, which usually remain until nearly all the spores have fallen. Some of the papery outer membrane usually remains attached to these fibers until eventually both fibers and membrane are weathered away. The reason, that notwithstanding the presence of fibers and a thin enveloping membrane, this species sheds its spores very readily

and seems wholly different from typical Ustilago hordei, is found in the fact that the spores are completely free, and do not adhere to each other or to the shreds of the host tissue. The infected heads, unlike those of Ustilago hordei, grow to their normal height, and do not tend to remain inclosed by the uppermost sheath of the barley plant.

In botanical and microscopic characters of the smut, the spores of this species are perfectly free from each other, and form a dusty mass of dark, dusky olivaceous color. In shape, the spores of this species differ very markedly from those of U. hordei, being oval, or less often elliptical or subglobose. The spores are regular in shape, and only rarely present abnormal forms. In size, the spores are 4.5-8 x 4.5-6 microns, mostly 5-7 x 5-6.5 microns, and probably the least variable of all the four species studied. The spores of this species are somewhat smaller than those of U. hordei, a fact that has been noted by Jensen, Kellerman and Swingle (1889).

As in the other loose smuts, the spore wall is composed of two layers, the epispore and the endospore. The two are, however, hard to distinguish in this species. These two layers together from a wall 1-2 microns in thickness. Outside of the wall a thin, delicate, hyaline layer, the cuticle of Fischer von Waldheim, can often be seen, especially on the dark side of the spore. It is always very faint, but is rendered somewhat more distinct by the use of potassium hydrate or nitric acid.

As in the other loose smuts, one side of the spore is plainly lighter colored than the remainder. An area of perhaps one-quarter or even one-half of the whole surface is much lighter in color, while the

opposite portion of the wall is very dark; between these two extremes the wall shades gradually in color. The promycelium always arises from some part of the light-colored area. The wall, as well as its two layers, can be most clearly seen in the part of the wall between the lightest and darkest portions. Often the two layers of the wall can be plainly seen in this part, when they can be distinguished only with much difficulty on the darkest part, and not at all in the light area.

The epispore in this species is covered with minute spines or warts, which show plainly in profile, and can usually be seen in optical sections along the light part of the wall, but not at all along the very darkest portion. On the light side of the spore there is usually a space free from spines; the spines or warts are quite numerous, but are not very thickly or regularly set, the distance between them being .5-2 microns; usually about 1-1.5 microns.

The promycelium is scarcely contracted where it passes through the wall, either in cultures in nutrient solution or in water. Often the wall in such cases splits down from the opening, and in some cases the wall is then dissolved away, leaving a wide crack which may extent entirely across the spore.

In germination in water, the spores after remaining a number of hours in water (somewhat longer than for U. hordei) sent out a single hyaline germ tube, which at first appeared as a minute elevation on the surface of the spore; it at length grew to a straight or curved slender promycelium. By 20 hours, at a temperature of 18-25° C., the promycelia were 20-46 microns long and 2.5-4 microns wide; continuous, or one to three septate; often with one or two knee-joint fusions, and rarely

branched. These promycelia, unlike those of U. hordei, throughout their growth always remained attached to the spore. No sporidia whatever were produced at any stage of growth or decay. There was not the slightest tendency observable to break into segments, or in any throw off fragments.

In germinating this smut in nutrient solution, the cultures at first much resemble those described for water. The promycelia are of about the same size and shape, though perhaps less often and less plainly septate. The growth of the promycelia did not cease so soon as in water cultures, but lateral branches arose in many cases. After 48 hours little change occurred, except that the free ends of branches and promycelia became swollen. At no stage of the growth were any sporidia formed, and no detached segments of promycelium were seen.

Jensen, according to Kellerman and Swingle (1889), finding that solutions which kill the spores adhering to the outside of the grain do not prevent the smut, says: "Hence we must conclude that the infective medium is internal, not external, to the covering of the seed corn."

He also found that treatments which controlled the other smuts did not prevent infection of U. nuda. Heating the seed barley five minutes in water at 127° F., after it had previously been soaked eight hours in cold water, prevented the smut completely, in later experiments, Jensen obtained best results from the following treatment: "Soak the barley seed four hours in cold water, and then let it stand four hours longer in a wet sack. Finally dip and drain for five minutes in water of a temperature of 126-128° F., after which dry and plant."

The temperature must not be above 128° F., since the soaked seed would then be injured, and not below 126° F., for then not all the smut would be killed. Instead of soaking four hours and letting the seed

stand four hours longer in a wet sack, it may be simply soaked eight hours, drained, and then treated with hot water.

The covered barley smut will be also completely prevented by these means. But since this (covered) smut is capable of infecting grains to which it adheres externally, care must be taken to prevent any smut from reaching the treated grain.

The original description of Ustilago nigra Tapke (1932), which is really a comparison of the two loose smuts, follows:

> As a result of further studies on the infection of barley by the loose smut fungus through seed inoculation discovered by Tisdale and Tapke, it has been found that loose smut of barley is caused by either of two fungi: (1) Ustilago nuda (Jens.) Kell. & Sw. and (2) a darker spored species for which the name Ustilago nigra n. sp. is proposed. The two smuts are readily separable, as shown below.

Color of spore mass.....	Olivaceous brown	Dark chocolate brown
Individual spores		
Color.....	Golden brown	Dusky brown
Size.....	5.5 x 6	6.5 x 7
Duration of viability....	3 to 6 months, rarely 1 year	Over 18 months
Control of loose smut in plants from seed from inoculated flowers following treatment of the seed with Ceresan dust or liquid formaldehyde (1-320, seed soaked 90 minutes)	No control	Complete control
Ability for the fungus to cause seedling infection resulting from inoculation of mature seed with chlamydospores	No seedling infection	Seedling infection

In the light of the above, the divergent results obtained by investigators in the production of loose smut of barley through dusting mature seed with chlamydospores and in the control of loose smut through seed treatment with surface disinfectants, might be explained.

In comparative studies of field collections of U. hordei and U. nuda, Ruttle (1933) obtained the following results:

	Head	Spore Mass		Individual spores		
No.	Type	Compactness	Color	Wall	Germination	Remarks
1.	Covered	Compact	Very dark chocolate brown	Smooth	Promycelia and sporidia	Typical U. hordei
2.	Covered	Less compact	"	Echinulate	"	sp. ?
3.	Loose	Powdery to compact	Dark chocolate brown	Smooth	"	sp. ?
4.	Loose	"	Less dark chocolate brown	Faintly to distinctly echinulate	"	U. nigra ? Blossom inoculation gave no infection
5.	Loose	Powdery	"	Echinulate	Much branched germ tubes	sp. ? Seed had been dusted with Ceresan
6.	Loose	"	Olivaceous brown	"	"	U. nuda ?
7.	"	"	"	"	Germ tubes not so branched as in 5 & 6	Typical U. nuda. Blossom inoculation produced 100% infected seed

According to Stevens (1913) in describing the barley smuts, U. hordei has sori in spikelets, forming an adhering purple-black spore-mass, about 6-10 mm. in length, covered rather permanently by the transparent basal parts of the glumes: spores lighter colored on one side, usually subspherical or spherical, smooth, 5-9 microns, the most elongate rarely 9-11 microns in length and common in barley. The spores germinate freely in water by one, rarely two, tubes, usually 4 celled, and produce abundant sporidia; these increase by budding, produce germ tubes or fuse

with each other.

U. nuda has sori in spikelets, forming a dusty olive-brown spore-mass, about 6-10 mm. long by half as wide, temporarily protected by a thin membrane which soon becomes dissipated leaving the naked rachis behind; spores lighter colored on one side, minutely echinulate, subspherical to spherical or occasionally elongate, 5-9 microns in length. It is distinguished from covered smut (U. hordei) by its olive-green spore-mass and its early shedding of spores. As a rule, each spikelet except the awn and rachis is entirely transformed into smut.

In water and nutrient solutions the spores germinate by a single promycelium, 1 to 3 septate, and often branch, but without sporidia.

The spores falling between the glumes germinate, penetrate the ovary wall and into the growing point of the embryo. The mycelium lies dormant until the seed germinates, at which time the smut keeps pace with the growing point of the barley plant throughout the season and finally invades the ovaries to produce its spores.

The embryo was reached by the mycelium some four weeks after infection of the pistil. In resting grains the mycelium is abundant in the scutellum as well as in all embryo parts except the roots. The optimum time for infection has been determined as the period of full bloom.

Dickson (1939) in discussing the barley smuts gives the following information: Ustilago nuda is found world wide in humid temperate regions. Smutted plants stand erect above healthy plants. The brown spore-mass is windborne over fields at blossom time, and produces a systemic invasion of the plant. The spore masses are dusty olive brown, the

chlamydospores lighter colored on one side, minutely echinulate. They germinate to form 1-4 celled basidium. Fusion between the cells of the basidium are followed by the growth of long slender branches. The mycelium is carried in the dormant state within infected seed, and resumes development when barley is sown.

Weather conditions play an important role in floral infection, thus accounting for the great variation in amount of infection. The smutted heads come out a few days before the other plants head thus infecting the normal heads to produce infected seed.

The treatment of the seed with hot water is the only known satisfactory seed treatment for the control of this smut.

A short discussion of Ustilago medians (intermediate loose smut of barley) is given here even though it is no longer recognized as a separate species.

U. medians is common in spring barley areas of central and eastern United States. Head symptoms vary from typical loose to semi-covered type. Smutted heads appear later and persist longer than loose smut. The spore mass is usually darker in color than in loose smut. Seedling infection followed by systemic invasion of tissues. Chlamydospores are dark to light colored, slight to marked echinulations; they germinate characteristically to form a basidium and oblong to elongate basidiospores (sporidia).

Seedling infection commonly occurs rather than floral infection. Chemical seed treatment can be used to satisfactorily control this disease. Also there are resistant varieties. Two physiologic races of the parasite have been described.

Ustilago hordei (covered smut of barley) is world wide. The spore masses are enclosed with the floral structures (palea and lemma) frequently with awns developing. Smutted plants frequently are shorter than healthy plants but heads emerge about the same time. The disease is systemic following seedling infection.

The adhering spore mass is covered rather permanently by a membrane and basal portions of floral structures. The chlamydospores are light colored on one side, subspherical to spherical, smooth, 5-9 microns in diameter, germinating to form 4-celled basidium and ovate to oblong basidiospores (sporidia) and abundant secondary spores.

Infection of young seedlings results from seed-borne chlamydospores. Development of mycelium in embryonic regions of host follows and finally production of spores occurs replacing kernels at heading. Spores are carried over on kernels. Seedlings are susceptible only during early stages of growth. The soil environment influences primary infection and development of smut after primary infection. The control recommended is organic mercury dust treatments and growing resistant varieties.

Bever (1942) describes a buff-colored barley smut, and this information is included here due to the possibility that it may be a connecting link in the changes that are taking place in the barley smuts.

Buff colored chlamydospores of certain smut fungi have been found to cause infection on graminaceous hosts. However, the nonpathogenic type had not previously been described. A single head of barley infected with what was described as an albino strain of U. hordei. The head was almost white, and intermediate between the loose and covered smut types. The spores were colorless, glabrous, and smaller than those of U. hordei and

the germination was typical of the sporidium-forming smuts. In a study of genetics and hybridization between a physiologic race of U. hordei and 2 races of U. nigra, on one plant of Nepal there were two identical buff smutted heads that contained F_3 chlamydospores. Except for color, these buff smutted heads were identical with those containing the usual black chlamydospores of U. hordei. The spores were hyaline, glabrous, and apparently intermediate in size between U. hordei and U. nigra. The sporidia were smaller than the sporidia of either U. hordei or U. nigra but more nearly approached the U. nigra type i.e. they were long and narrow and somewhat pointed. The spore germination was irregular, two or three sporidia instead of the expected four sporidia on a promycelium was rather common. The sporidia were difficult to detach from the promycelium.

Pathogenicity tests using either chlamydospores or paired monosporidial lines failed to produce smut on Nepal or Odessa barley.

Tapke (1941) gives a technique for identifying the loose smuts of barley which is given here in part.

> Two to three cu. cm. of melted 2 percent potato-dextrose agar are poured into a 60-mm. Petri dish. While it is hardening, a sterile transfer needle is thoroughly prodded into and among the loose smut heads in the sample and into the spore dust that usually accumulates on the bottom of the container. The needle is then dipped and shaken in about 2 cc. of sterile water in a test tube. This is repeated several times until a representative sample of spores has been put into the water and the latter shows a faint tint of yellow from the spores in suspension. After thorough shaking, the spore-suspension is poured over the surface of the medium in the Petri dish and allowed to stand a few moments until the spores settle to the agar. The water is then poured off and the base of the Petri dish is inverted and pressed down firmly on a clean blotter or paper towel to remove all free water. Moisture that may have collected on the inside of the cover of the Petri dish while the agar was cooling also should be flamed away, and the cover

replaced. With these precautions the spores will stick in place on the agar and not float about in excess water when ready for observation. The spores should then be left to germinate at 65-70° F. for 12-18 hours. The cultures are then usually ready for examination. Under these conditions, the spores of U. nuda germinate by producing only branching mycelial threads, while the spores of U. nigra produce a short promycelium whence four lateral sporidia normally develop. The sporidia multiply rapidly by yeast-like budding. When both U. nuda and U. nigra occur in the same collection, then, obviously, both the mycelial and sporidial types of spore-germination will take place. It is evident that with this technique an excellent distribution of spores over the surface of the agar is obtained. It is thus possible to observe the behavior of each individual spore and to determine precisely whether the collection is U. nuda, U. nigra, or a mixture of these.

Spores of the barley covered smut may be readily distinguished from those of the loose smuts, the former are perfectly smooth, the latter echinulate.

Tapke (1937) devised a way to inoculate seed barley with loose smut for use in studies on physiologic races. In previous experiments on the black loose smut of barley he obtained high percentages of smutted heads as a result of blackening the seed with dry smut spores. Although effective and easy to apply, this method presents an inherent difficulty when used in physiologic race studies involving many different smut collections that must be prevented from mixing. The dry spores are so volitant that it is difficult or impossible to keep them confined, even by the most careful handling, in the preparation of inoculum by removing the spores from the smutted heads and in applying the smut dust to the seed. Furthermore, if the dusted seed is placed in envelopes and the latter are squeezed in handling, puffs of smut emerge from the corner vents of the envelopes and a further spread of the smut occurs.

To avoid this difficulty the wet method of preparing the inoculum was devised. The inoculum is then applied to the seed by the spore-suspension method, the method as used in recent studies of physiologic races of U. nigra is as follows:

> Four loose smut heads are immersed in 750 cc. of water in a 1-liter Erlenmeyer flask. By vigorously shaking the flask the spores are loosened from the heads and suspended in the water. The suspension is then poured into another vessel through a fine screen to remove the remnants of the smutted heads and other extraneous matter. This spore suspension is then used to inoculate thoroughly dry seed, previously treated by the modified hot-water method for the prevention of loose or covered smuts. The fluid is poured over small lots of seed in shell vials until it rises about 3/4 inch above the seed. The seed is vigorously shaken in this suspension for 1/2 minute then allowed to soak 15 minutes. The suspension then is decanted and the vials are inverted on clean pieces of blotting paper to absorb all free water. Next, the vials of moistened inoculated seed are packed, uncorked, in a tightly covered tin box floored with a wet blotter to maintain high humidity, and then incubated for 24 hours at 18-20° C. Lastly, the seed is transferred to small envelopes, crimped to remain wide open, where it is left 2 or 3 days, or until thoroughly dry. It is then ready to sow.

Tapke further stated that through the cooperation of the North Carolina Agricultural Experiment Station and the Division of Forage Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, a field planting of 25 varieties of winter barley, each inoculated by this method with 10 different collections of U. nigra was made at Statesville, North Carolina, in the fall of 1935. Despite the severe winter of 1935-36, high percentages of smutted heads, reaching a maximum of 83 percent were obtained in the spring of 1936. It is, therefore, evident that the method is highly effective. Moreover, it has the desirable feature of practically eliminating the hazard of mixing the smut collections, so troublesome in the dust method.

Tapke (1940) made studies on the natural inoculation of seed barley with covered smut and the following information is given. A practicable and effective artificial method of inoculating seed barley with covered smut has been diligently sought for many years. No satisfactory method being available, it has been difficult to determine adequately the smut resistance of barley varieties and to breed for resistance against the heavy annual toll of covered smut. Years of general observation have convincingly established the fact that inoculation of seed as it occurs in the usual field culture of barley is effective and frequently results in high percentages of smut.

It has long been generally considered that, under the natural or field conditions of inoculation, spores of barley covered smut are held in the smutted heads until threshing and that inoculation comes about when the smutted heads are disintegrated in threshing and free spores stick to the surface of the seed hulls of barley. The artificial blackening of seed with millions of spores, however, repeatedly has failed to result in good infections. Furthermore, the treatment of naturally inoculated seed with certain surface disinfectants usually has failed to result in satisfactory control, indicating that the effective inoculum is beneath rather than upon the seed hulls.

Through a study of naturally inoculated seed lots, it was found that the most effective inoculum consisted not of spores upon the seed hulls but of spores and of extensive ramifications of mycelium from germinated spores on the pericarps of the caryopsis beneath the seed hulls. The occurrence of this sub-hull inoculum in nature evidently explains why copper carbonate dust, formaldehyde solution, and some other surface

disinfectants of seed barley repeatedly have been reported as being relatively ineffective in the control of covered smut throughout most of the barley growing areas.

In the light of another discovery on the covered smut of barley that has been recently reported, it seems possible now to explain also why the subhull inoculum of naturally inoculated seed has been generally effective. It has been shown that when seed is sown and the inoculum is beneath the hulls, the pathogen is frequently able to establish such a deep-seated infection of the seedling before it emerges that exposure to cold after emergence has relatively little adverse influence on infection. When the inoculum resides on the exterior of the seed, however, the nature of the infection is such that exposure to cold after the seedlings emerge usually promotes a lowered incidence of smut. High infections may occur, but they are dependent on the hazard of a moderate climatic period of several weeks or more following emergence.

It was found that all of the spores of barley covered smut are not held intact in the smutted heads until threshing, as has been generally reported. A few days after the smutted heads emerge, the membranes that enclose the spores begin to split, thus permitting an early dissemination of spores and an early inoculation of developing seed in healthy heads. Disintegration of smutted heads, dissemination of spores, and inoculation of seed continue throughout the development, maturation, curing and drying of the standing and shocked grain, and culminate with the completion of threshing.

All the spores that reach the seed do not lie dormant on the surface of hulls until seeding. Some that are blown, washed, or otherwise carried

to the seed from heading to threshing time may come to lie beneath the hulls or send infection hyphae beneath the hulls or both. Likewise, spores that reach the seed during threshing also may send infection hyphae beneath the hulls under certain conditions of moisture during storage. Thus, beginning a few days after the smutted heads emerge and continuing to the time when the seed is sown, the pathogen may pursue its course in the subhull region of the seed.

The recently extended knowledge of factors that condition the infection of barley by Ustilago hordei has aided in the development of the spore-suspension method of seed inoculation. This is a new artificial method, patterned after the natural method, that has proved to be highly and consistently effective as well as practicable.

Adequate testing of the reactions of varieties and selections of wheat and barley to loose smuts, as well as an extensive study of physiologic specialization in the smuts themselves, depends largely upon the use of a rapid and effective method of inoculation. Moore (1936) described an apparatus devised to subject the wheat or barley head to a partial vacuum while completely submerged in an aqueous spore suspension. In this way as many as 30 heads per hour can be inoculated. Inoculation somewhat reduces the number of seeds that develop per head. For this reason, only the most vigorous heads should be selected for treatment. The most favorable stage of development, both for set of seed and for infection, seems to be just after anthesis in most of the florets and before the ovaries have more than doubled their original size. According to Oort (1939), the moment of inoculation is of great importance. In two

days the percentage of loose smut decreases from its maximum of 84 percent down to 18 percent. For barley, therefore, even more than for wheat, the inoculum should have been applied at the right moment.

According to Tapke and Bever (1942), covered smut of barley, U. hordei Lagerh., causes considerable loss, much of which can be avoided by growing smut resistant varieties. Progress in this direction, however, has long been hampered by the difficulty in getting high percentages of smutted heads in susceptible varieties through artificial inoculation of the seed. It has been repeatedly observed that when seed from a smutted crop is threshed, stored, and then sown without treatment, high percentages of covered smut frequently occur. Paradoxically, however, when clean seed is artificially inoculated by superficially blackening it with millions of spores, only low percentages of smutted heads usually appear. This has been difficult to understand in view of the belief that spores of covered smut remain enclosed in the smutted heads until threshing, when the smutted heads are disintegrated and spores come in contact with the surface of seed. In studies to clarify this, it was found that many spores and extensive ramifications of mycelium from germinated spores were found beneath the hulls of naturally inoculated seed. This subhull inoculum, moreover, proved especially effective in infection. Also it was found that blackening of seed with smut spores is far more effective in smut production if the hulls are first removed.

The spore suspension and vacuum methods, both proved far more effective in smut production than the well known method of inoculating seed by coating the surface with spores. The spore-suspension and vacuum methods involve three essential features: (1) The seed is first treated

for an hour with formaldehyde solution, then washed in water and dried. This treatment eliminates superficially borne foreign inoculum, loosens the hulls around the caryopsis, and materially increases the effectiveness of inoculation. (2) The seed is covered with spores in suspension. Spores are thus carried beneath the hulls and come to lie close to the point of attack as in the effective natural inoculation. (3) Inoculated seed is stored 16 to 20 hours while moist. This promotes spore germination and spread of inoculum before seed is dried and sown. The vacuum method has been slightly superior to the spore suspension method in smut production but with large scale inoculations, particularly in studies of physiologic races, the latter method appears to be easier and safer to apply.

Bever (1945) reported findings on hybridization in smut. It is well known that new strains of fungi pathogenic on plants may result from hybridization of existing species or races. Such strains are known particularly in the rusts and in certain smuts. Although it has been shown that certain species of the genus Ustilago on barley may hybridize, it has not been clearly demonstrated that new physiologic races may result.

There are at least three species of the genus Ustilago occurring commonly on barley. As early as 1888, investigators recognized two kinds of smut on barley: covered smut, caused by Ustilago hordei (Pers.) and loose smut, caused by U. nuda (Jens.) In the head smutted with U. hordei, the chlamydospores remain enclosed for a time by a membrane; the spore walls are smooth; and the spores normally germinate by producing a promycelium that bears sporidia. In the head smutted with U. nuda the spores

are not enclosed long in a membrane but are liberated soon after the heading of the barley. The spores are echinulate and germinate by forming non-sporidia-bearing promycelia. U. hordei infects the very young seedlings, whereas U. nuda infects the young immature ovary during or soon after anthesis. In 1894, Biedenkopf, Bever (1945), inadequately described what he considered a third species, U. medians Bied., in which he noted both types of spore germination described above.

More recently, investigators of barley loose smut in the United States have obtained unexpected results. For example, the long-accepted belief that loose smut of barley is controlled only by the hot-water seed treatment was brought into question when certain workers obtained partial to complete control of loose smut with the formaldehyde seed treatment. Furthermore, Tisdale et al obtained loose smut infection of barley grown from seed superficially inoculated with what was interpreted to be U. nuda, whereas the original work with this species had indicated blossom inoculation as the only means of obtaining infection. The possibility that different physiologic races of U. nuda might enter the host by different means was suggested by Tisdale and Tapke as an explanation of such results. The correct interpretation of these and similar results obtained by others in seed-treatment experiments was developed by Tapke in 1932, when he demonstrated the existence of a second loose smut of barley, which he described and named U. nigra. In this and subsequent studies Tapke reported consistent differences between U. nuda and U. nigra in method of infection and response to control through seed treatment with surface disinfectants. These two species were shown to differ also in type of chlamydospore germination; the echinulate chlamydospores

of U. nigra normally germinate by forming a short promycelium bearing four lateral sporidia. Tapke has also pointed out that U. medians Bied. cannot be accepted as a valid species because it was doubtless erroneously based on a field mixture of U. nuda and a sporidia-producing smut that may have been similar to U. nigra.

The optimum temperature for chlamydospore germination of U. nigra and U. hordei ranged from 24° to 28° C. Chlamydospores of U. hordei germinated over a wider temperature range than did those of U. nigra. At 36°, U. nigra failed to germinate.

In hybridization experiments with the two smuts, the following information was given. Ustilago hordei hybridized readily with U. nigra as was evidenced by sporidial fusion in culture and by the production of hybrid chlamydospores in the host plants.

Interspecific crosses and backcrosses failed to show simple Mendelian inheritance of chlamydospore markings or pathogenic properties, nor did the smutted head types segregate in any such ratio.

The smutted heads produced from a monosporidial interspecific cross ranged in the F_1 from almost typical Ustilago nigra to the U. hordei type.

The backcrosses of the interspecific hybrids on the U. hordei parent tended to produce smutted heads of the U. hordei type. In contrast to this, the backcross of the interspecific hybrid on the U. nigra parent produced all types of smutted heads, ranging from the true U. nigra type to the true U. hordei type.

In the F_2 of the interspecific hybrid there was some correlation between the chlamydospore markings and the type of smutted head. Most

smutted heads of the U. nigra type had echinulate spores, whereas the the smutted heads of the U. hordei type had smooth or echinulate spores with approximately equal frequency.

Evidence was secured indicating that the range of virulence of Ustilago nigra and U. hordei may be combined through hybridication, thus forming new physiologic races.

In a discussion of the occurrence, identification, and species validity of the barley loose smuts, Tapke (1943) stated that the discovery that loose smut infection could be produced by inoculating the seed as well as the flowers and also that seed treatments with certain easily applied surface disinfectants which often resulted in excellent control led to the discovery of different kinds of loose smut of barley, namely U. nuda, U. nigra and U. medians. All reports fully agree that U. nuda produces the loose type of smutted head and that its chlamydospores are echinulate and on germinating, normally produce only branching filaments. Some observers say U. nuda may be induced to form sporidia by germinating the spores at freezing temperatures while others found that its promycelial cells separated under these conditions but formed no sporidia.

U. nigra, also, is an echinulate-spore fungus. The chlamydospores, however, normally germinate by producing a promycelium bearing typically 4 lateral sporidia. Referring to the third species of barley smut known as U. medians, it has been reported that it consistently formed sporidia on potato dextrose agar. Several intermediate barley smuts have been described which are similar to U. nigra that produced sporidia. In studies of U. nigra on grasses when the chlamydospores were germinated on potato-dextrose agar, sporidia were obtained as with U. hordei. This indicates

that it should not be difficult to distinguish U. nigra from U. nuda through difference in type of spore germination.

U. medians was described as forming echinulate chlamydospores that germinated in a most unique manner. When sown on gelatin, some produced the mycelial germination typical of U. nuda, but the majority formed a promycelium and sporidia typical of U. hordei. The observer (Biedenkopf) thought he might have in one smutted head a mixture of the echinulate spore, mycelium producing loose smut (U. nuda) and the smooth-spore sporidia-producing covered smut (U. hordei). But upon examination of the heads no covered smut was found as all the spores were echinulate. In a second test the spores were sown in diluted plum decoction and germinated within 4 hours. Again both the conidial and mycelial types of germination occurred. In the first test most of the spores formed sporidia but in the second test most of the spores formed mycelium.

Biedenkopf's excellent descriptions leave no doubt but that his U. medians was an echinulate-spore loose smut of barley with a mixed mycelial-sporidial type of spore germination, similar to or identical with that produced by a mixture of U. nuda and U. hordei. Therefore, if U. nuda, U. nigra, and U. medians have been correctly described, the morphological character that should distinguish the three species is the mycelial germination of the spores of U. nuda, the sporidial germination of the U. nigra and the mixture of mycelial and sporidial types produced by the chlamydospores of U. medians.

Tapke later concluded that U. medians is but a mixture of U. nigra and U. nuda by methods of inoculation, and is not considered a separate species.

In determining the distribution of intermediate types of barley smuts, Moore and Allison (1934) made collections of barley from various places. About 700 samples of barley seed were obtained from Minnesota, and about 125 samples from other states. Seed from these samples were sown in 1935 and the smutted heads, which appeared in about half of the plots were examined for head type and color of spore mass. The spore-wall character and type of germination of the chlamydospores also were determined. Smutted heads collected in barley fields were similarly examined. Results show that in addition to U. hordei and U. nuda, U. medians is widely distributed from North Caroline to Colorado and Missouri to Minnesota. More than one kind of smut often occurred in the same sample, occasionally two in the same head. Chlamydospores in one "Loose Smut" head were smooth and produced sporidia on germination. U. nuda and U. medians could not be differentiated by head type or color of spore mass. Heads determined as being smutted by U. nuda fell into at least two color groups.

According to Moore (1936) various collections of U. nuda were inoculated by the partial vacuum method into differential varieties of barley. The results were not consistent enough to permit the separation of parasitic races, but did indicate that Trebi is rather highly resistant to the nine collections of U. nuda used.

In an experiment (Tapke 1936) to study pathogenic strains in U. nigra, the following procedure was carried out. In the spring of 1935, ten collections of black loose smut of barley were used to inoculate 17 varieties. The smut collections had been increased on Alpha barley in the greenhouse during the winter of 1934-35 and were less than a month old and

highly viable at the time of inoculation. Prior to inoculation, seed of the 17 barley varieties was treated by the modified hot-water treatment (five-hour presoak followed by 13 minute treatment at 52° C.) to insure freedom from any previous infestation of smut. The inoculated seed was sown in 8-foot rows in duplicate series in May, 1935, at Ithaca, New York in cooperation with the New York (Cornell) Agricultural Experiment Station. In July, the results were obtained. The results indicate that varieties Himalaya, Lion and Nepal differentiated collection 186 from Wisconsin as a distinct pathogenic strain. The other nine collections were pathogenically similar on this set of varieties.

In the fall of 1935, collections 185 and 186 were used again to inoculate smut-free seed of Himalaya, Lion, and Nepal. The inoculated seed was sown in November 1935, in a greenhouse at the Arlington Experiment Farm, Rosslyn, Virginia. Collection 185 again failed to produce smut in Himalaya and Nepal but did produce 100 percent smutted heads in Lion. Collection 186, on the other hand, produced 68 percent smutted heads in Himalaya, 30 percent in Nepal and only 16.7 percent in Lion. Each percentage is based on a total of approximately 100 heads.

The greenhouse results, therefore, confirmed the earlier field results in showing that pathogenic strains occur in U. nigra.

Sumeson and Houston (1942) suggest a male sterile barley as a new tool for the plant breeder for study of floral infection, and it appears to provide a means for mass inoculation of barley flowers with cultures of disease producing organisms transmitted by floral infection. The procedure should be particularly useful in studies of conditions affecting infection. The tests with loose smut involved mass dusting with both

pollen and smut spores. Infections of loose smut were rather low. This may have been due to varietal resistance, low atmospheric humidity at the time of infection, or to poor viability of the smut spores, as it has been shown that viability of loose smut spores is soon lost.

Livingston (1942) is discussing the inheritance of resistance to U. nuda says that flower-infecting loose smut, caused by U. nuda is one of the most widely recognized diseases of barley in the midwest. The modified hot-water treatment for destroying the dormant mycelium of U. nuda within the barley seed is difficult to apply and, even under carefully controlled conditions, may cause some damage. It is desirable therefore, to have available varieties that are resistant to the attack of this fungus.

The exact nature of the inheritance of resistance in barley to U. nuda was not determined because of the failure to identify all susceptible and segregating genotypes. An inoculation method that will give 100 percent infection with U. nuda has not yet been devised. Another complicating factor is the possibility of the presence of several physiologic forms of U. nuda in the inoculum even though the inoculum supply was built up from a single infected head. The inheritance of resistance to loose smut caused by U. nuda, was studied in barley hybrids. The two susceptible varieties were Missouri Early Beardless and Colsess IV, and the resistant varieties Trebi and Hordeum deficiens were used as parents. Both Trebi and Hordeum deficiens apparently possess a dominant factor for resistance, but dominance may not always be complete.

In F_2 and subsequent generations there was a preponderance of resistant plants, possibly attributable to lethal effects of infection,

variations in percentage of infection obtainable by the methods used, and to failure to obtain universal infection of the susceptible parent. The susceptibility of F_2 hybrids from a Colsess IV x Missouri Early Beardless cross approached the infection limits of Missouri Early Beardless but was less than that of Colsess IV, suggesting the occurrence of a weak resistance factor in Missouri Early Beardless.

The susceptibility of first selfed backcross generation progenies was in agreement with the susceptibility of F_2 and subsequent generations, offering additional evidence for the presence of a single dominant factor for resistance in Trebi and Hordeum deficiens, and possibly a weak factor for resistance in Missouri Early Beardless.

There was no evidence of linkage between the factors for resistance and those for hoods or six-rowness.

Tapke (1935) in a study of the cause of variability in response of barley loose smut to control through seed treatment with surface disinfectants says that during the past 20 years it has been frequently reported in the United States that loose smut in barley may be reduced or eliminated through treatment of the harboring seed with certain easily applied surface disinfectants. This is at variance with the reports of all of the earlier and some of the recent investigators, who have found that it is necessary to apply the difficult modified hot-water treatment or its equivalent in order to control loose smut in barley through seed treatment.

The present investigation has shown that in addition to the well-known loose smut of barley caused by U. nuda, a second barley loose smut caused by U. nigra is widely distributed and causes considerable loss in

the United States. The latter species is controllable through treatment of the seed with certain surface disinfectants, and doubtless has been the factor responsible for the conflicting reports noted above.

U. nigra resembles U. nuda in the appearance of the smutted heads, in the emergence of smutted heads and dissemination of spores during the heading and flowering period of unsmutted plants.

U. nigra may be distinguished from U. nuda by the following characteristics: (1) The color of the spore mass of U. nigra on fully emerged heads is dark chocolate-brown, whereas that of U. nuda is olivaceous brown. (2) In seed from flowers inoculated at blooming, U. nigra is amenable to control through seed treatment with certain surface disinfectants. The modified-hot-water treatment or its equivalent is necessary to control U. nuda. (3) On a 2 percent potato-dextrose agar at 70° F., the spores of U. nigra germinate by producing a promycelium bearing typically four lateral sporidia. Under these conditions the spores of U. nuda produce a promycelium that does not bear sporidia. (4) U. nigra is able to produce smutted plants through infection of the seedling as a result of inoculating mature barley seed, as well as through infection of the flowers. U. nuda is able to produce infection only through the flowers.

Some of the most important varieties of barley in the U. S. are highly susceptible to U. nigra.

To facilitate distinction, the terms "brown" and "black" loose smut of barley are proposed for U. nuda and U. nigra, respectively.

The most prevalent and widely distributed physiologic races of covered smut and black or shallow-borne loose smut in the U. S. are race 6 of U. hordei and race 4 of U. nigra.

Odessa barley is highly susceptible to all known races of covered smut and the shallow borne loose smut. Therefore, it is recommended as a standard. This is special strain Odessa (C.I.934) and not the commercial strain. It is highly susceptible also to the deep-borne loose smut which can be controlled only by the hot-water treatment.

The inoculum of covered smut most effective in producing the disease and also most difficult to combat is that found beneath the hulls, thus seed should be used that carries an abundance of inoculum beneath the hulls. The same is probably true of U. nigra. The partial vacuum method and standard spore suspension is recommended.

In covered smut the soil reaction may range from pH 6 to pH 7 and for black loose smut the range appears to be still greater. A soil reaction of pH 6.5 and a temperature of 20° C., during emergence are suggested for both of these smuts.

Livingston (1947) in discussing experiments with barley fertilizers and seed treatments says that in tests with various N and P fertilizers along with New Improved Ceresan, no significant stand differences were obtained in any of the tests as a result of seed treatment or the application of fertilizers. There were differences in the number of stems per five foot length row but these differences appeared to be associated with the differences in yield obtained with the various treatments.

Although the damage from root rot fluctuates from year to year, the value of seed treatment from the standpoint of smut control alone makes seed treatment a practice to be highly recommended. When combined with fertilizer applications, it may become even more beneficial by reducing the damage from root rots.

The effect of disinfectants upon the germination of seeds kept in storage for indefinite periods after treatment has been studied by Orton (1928). In experiments with various organic mercury dusts after indefinite periods of time after treatment, the dusts did not decrease the germination of various seeds and often increased it after periods of one to three years. Copper carbonate dusts were injurious on Navy and Black Valentine Beans. Dusts composed of $HgCl_2$ and oxide of copper caused decreased germination in some cases. However, liquids containing organic and inorganic mercury and water are more likely to be injurious, and water is especially so. Formaldehyde was also injurious in some cases. Barley was not one of the seeds used in this experiment but it is assumed that similar results would be obtained.

Experiments with the germination of fungus spores in relation to controlled humidity have been performed by Clayton (1942). The experiments with U. hordei were made with chlamydospores that were brushed from a few smutted heads of barley into a vial where they were kept until used. In preliminary tests, germination of the 6- to 8-month-old spores on water ranged between 30 and 57 percent. The controls on redistilled water started to germinate within 3 hours and germination after 48 hours on redistilled water on glass or paraffin was approximately 40 percent. The mean germination on glass at a relative humidity of 100 percent was less than half that on redistilled water. At a relative humidity of 99 percent, the mean germination was only slightly lower than at 100 percent. The mean percentages of germination on glass at relative humidities of 95, 98, 99 and 100 percent, respectively, were almost always higher than on paraffin. Spores on glass or paraffin failed to germinate at a relative

humidity of 93 percent or below.

Production of sporidia was fairly low on redistilled water, very sparse at a relatively humidity of 100 percent and absent at 99 percent or below.

Long primary basidial hyphae grew from the basidia at relative humidities of 100, 99, 98, or 95 percent. The average lengths of the basidia, together with the longest basidial hyphae at a relative humidity of 100 percent after 24, 27, 35 and 48 hours, respectively, were 62, 81, 150 and 217 microns. The basidial hyphae at the lower relative humidities at which germination occurred were only slightly shorter than those at the higher relative humidities.

The chlamydospores of U. nuda were obtained from a few smutted heads of barley of Hybrid x 163. The germination of the chlamydospores in or on water in preliminary tests ranged between 1 and 13 percent. Two series were made for 48 hours on glass at various relative humidities from 88 to 100 percent.

In the controls the average germination was 2 percent in redistilled water and 7 percent on the surface of it. On dry glass at relative humidities from 99 to 95 percent the average germination was higher than on water. The percentage germination at a relative humidity of 100 percent was significantly greater than at 98, whereas it was lower at 95 than at 99 percent. At 93 percent relative humidity or below no germination occurred in two series of experiments.

The germ tubes from spores in water were relatively short; whereas, at relative humidities of 100, 99, 98, or 95 percent, they were very long. The average length of 25 germ tubes from spores in water and at a relative

humidity of 95 percent, respectively, for 48 hours was 33 and 222 microns.

It was found by McClellan (1942) in studies on temperature as it affects spore germination in the presence of copper and sulphur, that toxic materials are least effective at the optimum temperature for the organism concerned and that both above and below this optimum temperature these materials are more toxic. It would seem from those data that in order to destroy a particular pathogen, it would be better to apply a toxic material when the temperature is above or below the optimum temperature for the organism. However, the time required for the killing of an organism by a toxic agent at temperatures below the optimum for that organism would probably be longer than that required at a higher temperature. Therefore, in most cases it would be desirable to apply a toxic agent when the temperature is above the optimum. These data deal only with spore germination. In all cases in this experiment Copper Sulphate and Sulphur were least effective at the optimum spore germination temperatures of the organisms employed.

Rodenhiser and Maxwell (1941) have made studies on the effect of X-radiation on the germination of chlamydospores of U. hordei. Previously, X-radiation of smut fungi has been studied primarily as a means of controlling the organisms and in general the studies indicate that differentials in the killing points of the hosts and smut fungi usually are not large enough to control the parasite without serious injury to the host. In this study, percentage of germination was not materially affected by dosage up to 100 kr., at higher dosages the number of non-viable spores and the time required for germination of the viable ones increased irregularly with increasing dosage up to 1000 kr., at which all

of the spores were killed. There is some evidence that the degree of X-ray sensativity depends on some unknown physiological condition of the chlamydospores.

Irradiation of the chlamydospores at certain dosages resulted in increased elongation of the promycelia. It was noticeable at 30 kr. and progressively more marked at 60, 100 and 150 kr., at the latter dosage promycelial lengths were approximately 3 times normal. Septation was rare. Promycelia from chlamydospores irradiated up to 60 kr. developed a normal number of primary sporidia, at dosages of 100 kr. sporidia developed on only approximately 10 percent of the promycelia and at dosages of 150 kr. and above only an occasional sporidium was observed.

The normal growth processes in U. hordei are inhibited by X. radiation of lower dosages than is required to destroy the mechanism responsible for germination. Although as much as 80 percent germination was obtained with chlamydospores irradiated at 300 kr. development ceased after elongation of the promycelium. It is suggested that this effect be called a "delayed killing."

X-irradiation of chlamydospores at 60 and 100 kr. did not affect the rate of mutation in cultures of monosporidial lines of U. hordei.

Tapke (1940), in studies of preemergence and postemergence factors that influence the infection of barley by covered smut and nigra loose smut, says that these two smuts, like the other seedling infecting smuts of small grains, invade their host during seedling growth from the seed to the soil surface. Soil conditions during the preemergence period, especially moisture and temperature conditions, long have been considered the important factors affecting infection and the incidence of smut. In

line with recent results with barley covered smut and oats loose smut it was found that cold conditions, after the seedlings have emerged, also may result in marked reduction in the incidence of black loose smut of barley. Temperate conditions for 10 days, 30 days, and continuously after seedling emergence resulted in progressively marked increases in smut. In another study, distinct increase in covered smut was obtained through impeding the subterranean growth of the seedlings by tamping or deepening the soil layer above the seed or by using a heavy soil. In another experiment, the incidence of covered smut was more than doubled when the early growth of fully emerged seedlings was retarded through pruning the roots.

Tapke (1939) also has made studies on the influence of environment, after seedling emergence, on loose smut of oats and covered smut of barley. The seedling infecting smuts of small grains and sorghums invade their hosts during seedling growth from seed to soil surface, as indicated in preceding reference. Soil conditions during this period therefore, have been considered the important environmental factors affecting infection and incidence of smut. Recent studies of oats loose smut and barley covered smut indicate that environmental conditions after seedlings emerge may influence markedly the incidence of smut. Winter barleys and winter oats were grown outdoors and in a greenhouse after the seedlings emerged in autumn. When preemergence conditions included not only favorable soil factors but also favorable position of inoculum beneath seed hulls, deep seeding, high susceptibility of host and other factors, high and similar percentages of smut occurred under both the outdoor and greenhouse environments. When all preemergence conditions

were not ideal for infection of the seedlings, as frequently happens in field culture, the different environments after emergence effected striking differences. Under outdoor conditions at Arlington, Virginia, a low incidence of smut occurred. Under greenhouse conditions continuously after emergence or for only a month followed by transfer of plants outdoors, the incidence of smut was high. Evidently, the rugged outdoor environment sustained and the temperate greenhouse environment ameliorated the effects of the relatively unfavorable preemergence conditions.

In an experiment conducted with covered smut of barley at Arlington, Virginia (Tapke 1938), the following results were obtained: Field and greenhouse plants from noninoculated (control) seed were smut free. When the spore-suspension method of seed inoculation was used, covered smut in greenhouse plants, and in field plants regardless of the post-emergence treatment, was high and strikingly uniform. However, when seed was inoculated by superficially blackening with spores, covered smut was relatively low when the seedlings were first placed outdoors immediately after emergence, markedly increased as a result of first subjecting the seedlings to greenhouse conditions for two weeks after emergence and further increased after the seedlings were held four weeks in a greenhouse before transplanting outdoors. Evidently the placement and germination of spores beneath the hulls, as occurs in the spore suspension method of seed inoculation, enabled the fungus, from the time of sowing to seedling emergence, to become sufficiently entrenched within the host tissue to be unaffected by the subsequent external influences. In the spore-dusting method, however, the spores first must germinate after the seed is sown and the infection hyphae then must advance to the point of attack. It

would appear that under greenhouse conditions these delayed hyphae continued to advance in the tender, succulent tissues. On the other hand, under the rigorous field conditions of late autumn and winter and associated changes in the tissues of the barley plants, further advance of the infection hyphae was blocked and the percentage of smutted plants was greatly reduced.

The foregoing results at least appear to indicate that if the fungus has not become well entrenched with the host tissues before seedling emergence, then relatively low temperatures and other outdoor factors immediately after emergence may play a highly important role in decreasing the incidence of covered smut in barley.

Leukel (1936) in discussing the factors influencing infection of barley by loose smut says that the results obtained by experiments with U. nigra are as follows: Soil with a high percentage of saturation proved generally unfavorable for infection by U. nigra, especially at 5° C. and 30° C., while relatively dry soil favored infection at 5° C. At the other temperatures, differences in soil moisture from 30 to 55 percent saturation did not appear to influence infection. The cardinal temperatures for infection by U. nigra were found to be: minimum below 5°, optimum 15 to 20°, and maximum above 30° C. Fairly high percentages of infection were secured at soil temperatures of 10, 15, 20, and 25° C. U. nuda, on the other hand, showed little if any significant reaction to temperature.

Plants grown to emergence at 30° and then changed to a soil temperature of 15° showed less infection than those kept at a soil temperature of 30° C. until near heading. However, plants transferred at emergence

from a soil temperature of 13 to 30° or 5° C. showed a highly significant decrease in the percentage of infection compared with those kept at 13° C. Likewise, those similarly transferred at emergence from 5 to 13° and 30° C. showed significant increases in the percentages of infection, compared with those kept longer at the lower soil temperature.

Dusting the seed with dry spores of U. nigra resulted in heavier infection than inoculating the seed by means of a spore suspension in vacuum.

Results from experiments, in which emerging barley seedlings were inoculated with spores and with spore-infested soil, indicate that infection by U. nigra does not occur after the first leaf has emerged.

In experiments conducted by Tapke (1931) indicate that in areas of low humidity during flowering time or in seasons that are drier during flowering time the percentage of loose smut is definitely decreased.

The results of germination tests of smut spores for U. hordei performed by Fischer (1936) to determine the longevity of smut spores in herbarium specimens are as follows:

Age of spores years	Approximate percentage of germination on potato-dextrose agar after number days indicated				
	1 day	2 days	4 days	7 days	12 days
23	0	0	0	0	1.0
17	0	18.1	50	*	*
16	0	.1	20	-	-
14	0	0	.5	1.5	1
13	.5	1	2	10	*
11	90	*	*	*	-
7	45	75	85	*	-
7	80	95	*	*	-
5	35	90	*	-	-
5	45	80	*	*	-
2	95	*	*	-	-

*Impossible to determine increase."

An analysis of data obtained in this study reveals a surprising spore longevity for some smut fungi.

While, in general, the greatest longevity seems to be possessed by species in the Tilletiaceae, certain of the Ustilaginaceae are capable of retaining their viability over remarkably long periods of time. The greatest distinction goes to U. hordei, of which 16- and 17-year old specimens showed 20 percent and 50 percent germination, respectively, after 4 days, while a 23-year-old specimen showed 1 percent germination after 12 days. The greatest longevity established heretofore for U. hordei was 7 years.

The results of this study seem to lend support to the opinion that within a species the state of maturity at the time of collection determines, in a large measure, the longevity of the spores.

The spores of U. nuda are usually relatively short-lived. It is recommended that specimens held for later identification be stored immediately at 34-36° F. The duration of spore viability in both U. nuda and U. nigra is appreciably prolonged at these temperatures.

In recent studies on the longevity of smut spores Tapke (1948) gives the following information:

> Spores of many different collections of U. nuda and mycelium in seed from hand-inoculated flowers were stored at 32° F. in a refrigerator. At these temperatures some of the spores were still viable after nine years, whereas in storage at room temperatures, viability often declines appreciably in three to six months or less and seldom exceeds one year. Seeds of five barley varieties from flowers inoculated by hand in 1940 and stored at 32° F. were sown in a greenhouse in January, 1947. Sixty-seven percent of the seeds produced seedlings. In the variety Lion, 73 percent of the heads were smutted. Knowledge of the possibilities of cold storage for prolonging viability in U. nuda has facilitated study of its physiologic races and breeding for resistance.

Leukel (1930) is discussing seed treatment for controlling covered smut of barley says that covered smut in Tennessee winter barley was satisfactorily controlled by immersing the seed for one hour in any of the following solutions: Formaldehyde 1:320, Semesan 0.5 percent, Uspulum 0.5 percent, Germisan 0.25 percent, Tellatin 0.25 percent, Corona 620 0.25 percent, and Bayer compound 0.5 percent. Under average soil-moisture conditions covered smut of barley is deemed controllable by the more effective dusts, and in these experiments the dust fungicides, Hochst, Abavit B, and Ceresan, gave satisfactory control of covered smut of barley without injury to seed.

The effectiveness of the dust fungicides was apparently independent of soil reaction and, as far as could be determined, of the usual range of soil temperature. However, a soil moisture content of less than 25 percent of saturation decreased the efficiency of most of the dusts tested. The many advantages of dust fungicides over liquid fungicides for disinfecting seed grain are said to make it highly desirable to find effective and satisfactory dusts to replace liquids especially the formaldehyde and copper sulfate treatments, which often cause marked seed injury with consequent reduction in stand and yield.

Leukel (1936) further discusses this problem. It was noted that in two consecutive years barley from fields badly infected with covered smut produced crops with very low percentages of smutted heads.

Inoculation by the evacuation method or by applying dry spores to the seed with subsequent inoculation at from 25 to 28° C. under high humidity resulted in about two to three times as much covered smut as by application of spores by natural agencies only. Inoculation by the first

method produced a higher percentage of covered smut than by the second method, and the disease was less easily controlled.

Ceresan and New Improved Ceresan completely controlled covered smut and black loose smut. Soaking the seed in a 1:320 formaldehyde solution eliminated black loose smut and gave a fair but not complete control of covered smut. Formaldehyde dusts are not consistently effective, though some brands gave better control than others, none of the commercial dust fungicides used were injurious to the seed, even with storage for five months after treatment.

In discussing the control of smuts, Melchers (1938) said, "The only satisfactory dust treatment found so far for the covered smut of barley is New Improved Ceresan."

In discussing seed disinfectants for the control of smuts, Tisdale et al (1925) give the following information. The subject of seed treatment is one on which a large amount of investigation has been done. Yet it is a subject decidedly in need of further thorough and critical study. There is a striking need for disinfectants which will control seed-borne diseases and at the same time cause no injury to the treated seed. This demand has led scientific investigators and commercial organizations in the past to develop and study numerous chemical substances and compounds with the hope of finding something satisfactory. Of the several preparations tested, the great majority have proved worthless; others have limited use; while a few, including formaldehyde and copper-sulphate-lime have proved of sufficient value to bring them into extensive use. However, seed treatment has not been practiced as generally as the needs would seem to demand. This is true in the case of certain of the cereal smuts which

are comparatively easily controlled. One of the reasons for this lies in the fact that more or less seed injury often is caused by the generally recommended formaldehyde and copper-sulphate-lime treatments. Too often these complaints of seed injury have been explained away on the basis of improper preparations or handling of the treatment. It is now known that many factors may influence the effects of the treatment on the seed. Among the more important of these factors, not including variations that may occur in the material, its preparation and its application, are the kind of seed, the particular variety treated, the conditions under which the seed is grown and subsequently handled, and the local soil and weather conditions existing where the seed is sown after treatment. As these various limiting factors have made it almost impossible, even for the expert, to obtain satisfactory results with the treatments in use, there has been a keener interest in the search for disinfectants which are not injurious to the seed, at least within reasonable limits, as to strength of material and time of application. During the past decade investigations of this kind by both scientists and commercial organizations have become very intensive. Out of these studies a few materials of importance and promise have evolved. The more important of these are copper carbonate, the effectiveness of which is thoroughly established for the control of bunt in wheat, and some of the organic mercury compounds.

The literature dealing with the new materials, especially the mercury compounds, is becoming so voluminous that it is not desirable to attempt to review all of it here. Chlorphenol-mercury, the basis for such commercial preparations as Uspulun, Chlorophol, and Semesan, was used in Germany for the control of bunt in wheat as early as 1912, if not earlier.

In 1920, Germisan, another organic mercury preparation (probably cyan-mercury-cresol), appeared on the market in Germany. The reports concerning Germisan have about the same status as those dealing with Uspulun, indicating that it merits further consideration in our program of investigation in this country. Of the mercury materials prepared in this country, Semesan, Chlorophol, and Corona No. 620 have proved to be of value.

Copper carbonate has not proved satisfactory for the control of the smuts of oats and barley.

In the control of barley smuts, several of the organic mercury compounds, including Chlorophol, Corona No. 620, Germisan, Semesan, and Uspulun have given excellent results. In this experiment it is felt that the results with these compounds undoubtedly are superior to those obtained with formaldehyde from the standpoint of seed germination, smut control, and yields of plants from treated seed. These materials, however, are more expensive than formaldehyde and also are poisonous.

The active ingredients in the mercury compounds are absorbed rapidly by the seed and the solutions become weaker with use.

Formaldehyde, followed by a wash in clear water, does not cause the seed injury often resulting from formaldehyde alone, but in the case of barley, the control of smuts was not so satisfactory as was the control with formaldehyde alone.

Some of these new disinfectants have had a beneficial effect in most cases on the germination of machine-threshed seed taken from uniform seed lots of pure varieties. The yields have been improved in many cases, in some cases the increase in yield has been more than could be accounted for through smut control.

On the whole, the organic mercury compounds had been the most satisfactory fungicides up to this time.

In discussing the control of loose smuts by the use of Uspulun, Semesan, and Germisan, Rodenhiser and Stakman (1925) say that Uspulun (0.25% solution), Semesan (0.3% solution), and Germisan (0.25% solution), controlled loose smut of wheat and barley when the seed was soaked at 45° C. for one hour or longer. About 7 percent of the checks were smutted while only a trace of smut in the treated plants. Hot Germisan injured the seed slightly.

In results of experiments performed on barley, Tisdale (1926) stated that certain organic mercury compounds, including chlorophenol, cresol, and ortho-nitro-phenol derivatives of mercury have proved effective in the control of some of the cereal smuts, especially for the control of barley smuts. They do not cause seed injury as is true with formaldehyde and copper sulphate treatments.

In discussing the effectiveness of various fungicides in controlling the covered smuts of grains, Lambert et al (1926) stated that in this group of experiments none of the tests with barley were conclusive because there was very little smut in the check plots. However, formaldehyde seemed to control covered smut most effectively. Apparently none of the treatments injured barley seed.

Leukel (1926) stated that Germisan at .3 percent for one hour eliminated covered smut of barley completely, while Uspulun and Semesan reduced it to a very slight trace. Formaldehyde also gave fair control but reduced the percentage of germination. Corona 640-S, Copper Sulphate, and colloidal sulphur were unsatisfactory. Soaking the seed in tap water for

one hour seemed to increase greatly the amount of smut. The reason for this is not known.

Conners (1926) says that loose smut in hulless barley was not controlled by one-hour soak in Uspulun (0.25% solution), Germisan (0.25% solution) or Semesan (0.3% solution), at room temperature. Partial control was obtained with the solutions at 45° C. A presoak for one hour increased the effectiveness. Germisan was most effective but it injured the germination of the barley seed. The modified hot-water treatment eliminated the smut. The check plots showed nearly 10 percent smut in the barley.

In experiments carried on at Nanking, China, in 1925-26 with seed disinfectants for the control of covered smut, Porter (1928) gives the following results:

> In 1925, all the treatments reduced covered smut to less than 0.5 percent, the checks had 7 percent. In rod-square plots the checks had 27 percent smut and those treated with copper carbonate had but .5 percent. In 1926, copper carbonate and dry Uspulun eliminated smut entirely, while dry Tillantin "B" gave 0.87 percent and the checks averaged 6 percent. Increases in yields due to copper carbonate, Uspulun, and Tillantin "B" were 15.4%, 12.4%, and 20.7%, respectively, in 1926, while average yield of the checks was 13.0 bushels per acre.

With experiments conducted on hulless barley in the lower Yangtse river valley in China, Porter et al (1929) stated that using copper carbonate and dry Uspulun as control measures for covered smut of barley gave promising results. Copper carbonate and dry Uspulun reduced covered smut to an average of less than one-half percent. The copper carbonate had a different effect from that previously reported on

hull varieties, where no control was secured. No other treatments gave such consistently effective results as the two dusts mentioned above.

In investigating many materials for seed disinfectants, Tisdale and Cannon (1929) used ethyl mercury chloride and it gave effective results in control of disease but in some cases the seeds were injured. Combinations and strengths have since been prepared which cause no injury to the seeds of the small grains but give excellent disease control. Very satisfactory results have been obtained in the control of covered smut of barley and loose smut of Tennessee winter barley. For control of these diseases a thorough dusting of the seed with 1.5 percent product has been found sufficient.

In performing experiments with liquid and dust seed disinfectants for controlling covered smut of barley, Leukel (1929) stated that covered smut of barley was eliminated without seed injury by soaking seed one hour in 0.5 percent solution of Uspulun, Semesan, or Bayer compound or in 0.25 percent solution of Germisan, Corona 620, or Tillantin "C". Untreated seed had from 2.5 to 7.5 percent smut.

Among 40 dusts tested, Abavit B, Trockenbeize Tillantin, and Wa Wa reduced covered smut to a slight trace without seed injury and also reduced loose smut from 0.7 percent to a slight trace. Untreated seed produced from 3.6 to 12.2 percent heads affected with covered smut.

Extremes of soil reaction did not affect the fungicidal efficiency of the dusts used. Very dry soil conditions during germination and emergence reduced fungicidal action of the dusts.

MATERIAL AND METHODS

In conducting this series of field experiments, the following materials and methods were used: All plantings were made in eight-foot rows in the Barley Disease Nursery of the Department of Botany and Plant Pathology, Kansas State College, Manhattan, Kansas. Three plantings were made in 1947 (two in the spring and one in the fall) and one planting was made in the spring of 1948. The first spring planting in 1947 was made March 26, the second spring planting was made May 3, and the fall planting was October 11, 1947. The spring planting in 1948 was made on March 29.

The experiment designed to test the effect of chemical dusts on the emergence of spring barley and the control of smut was conducted as follows: Lots of seeds of Beecher, Flynn, and Spartan grown at the Hays, Kansas, Experiment Station in 1941 and the same varieties grown in 1946 were used. One group of seeds for each variety from the two dates grown was treated with Spergon at the rate of two ounces per bushel, one group was treated with New Improved Ceresan at the rate of one-half ounce per bushel and the third group was untreated to serve as the control. The seeds were treated March 15, 1947, and planted on two different dates, March 26 and May 3, 1947. Each treatment of the above plantings had 5 replications of 200 seeds each in 8-foot rows.

An experiment was conducted to determine the kinds of smut present, the percentage of smut and the distribution of the three species of barley smut found in farmers' varieties of spring barley throughout the state of Kansas. Farmers' samples of barley received at the Kansas State

Seed Laboratory, Manhattan, Kansas, were used for this experiment. Sixty-two samples were used for the 1947 plantings and 52 samples were used for the 1948 planting. Twelve grams of seeds were used for each eight-foot row. One lot of seeds for each sample was treated with Spergon at the rate of six ounces per bushel, one lot was treated with New Improved Ceresan at the rate of one and one-half ounces per bushel and the third lot of each sample was left untreated for the control. Two plantings were made in the spring of 1947, one on March 26, and the second planting was made May 3, 1947. The seed for those two plantings was treated on March 15, 1947. One planting was made in the spring of 1948, on March 29, 1948. The seeds for the 1948 planting were treated on March 26, 1948. The samples used for the 1947 plantings were presumably grown in 1946 and those for the 1948 planting grown in 1947. Entirely different samples were used for the 1947 and the 1948 plantings.

In the experiments to test the effect of hot-water treatment on the emergence of spring barley and the control of smut, the following procedure was carried out. All treated samples were presoaked a varying length of time ranging from no presoaking to five hours presoak in tap water (approximately 74° F.) then placed in a hot-water bath at 120° F. for two minutes for tempering, then placed in the critical treatment hot-water bath at 126° F. for 13 minutes. The samples were removed to a cold tap water bath for two minutes and finally spread out to dry on newspapers. All the seeds for the 1947 plantings were treated March 15, 1947, and the seeds for the 1948 planting were treated February 29, 1948.

One hot-water-treatment experiment was composed of the varieties Beecher, Flynn and Flynn x Vaughn cross. Each of these three varieties

was subjected to the following treatments: five hours presoak, four hours presoak, three hours presoak, two hours presoak, one hour presoak, no presoak, all followed by the remainder of the hot-water treatment as indicated above. Seeds for one row were left untreated for the control. These three varieties were grown at the Hays, Kansas, Experiment Station in 1946. Three plantings were made of this experiment. The first was on March 26, the second on May 5, and the third on October 11, 1947. All barley for these plantings was treated March 15, 1947. Each treatment for the three varieties of the above three plantings had replications of five rows of 200 seeds each.

The second hot-water-treatment experiment was with four lots of barley designated by their place of origin, namely: Colby (grown at the Branch Experiment Station, Colby, Kansas); Jansonius (farmer's name); Kindler (farmer's name); and Mahoney (farmer's name). Each of these lots was subjected to the following treatments: five hours presoak and remainder of treatment as outlined previously, three hours presoak, one hour presoak, and finally untreated as the control. All these samples were grown in 1941 and were of the variety Beecher. These were treated March 15, 1947 and but a single planting was made on March 26, 1947. Replications of five rows of 200 seeds each were made for each treatment of the above lots.

The third hot-water-treatment experiment dealt with the spring barley varieties of Atlas 46, Feebar, Flynn 1, Spartan, and Beecher. These varieties were received from twelve experiment stations throughout the mid-western and western sections of the United States, namely: Hays and Colby, Kansas; Lincoln and North Platte, Nebraska; Akron, Colorado; High-

more, South Dakota; Dickinson, North Dakota; Laramie, Wyoming; Moccasin, Montana; American Falls, Idaho; Moro, Oregon; and Lind, Washington.

In the above experiments, the data on the weight and moisture content of the seeds were taken immediately preceding the time of treatment, an extra lot of the seeds was weighed then placed in a dry air circulating oven for 48 hours and removed, and immediately weighed again to determine the loss of weight. This difference in the weight of the barley was taken to be the amount of moisture the seeds contained. The temperature of the oven during this heating and drying period was 104° C. Germination tests were made by the Kansas State Seed Laboratory. Tests for the 1947 plantings were run May 2, 1947, and for the 1948 planting, March 8, 1948.

Each variety from these twelve stations was treated with the following hot-water treatments: five hours presoak, three hours presoak, and untreated for the control. These treatments were made March 26, 1948, and planted March 29, 1948. Four replications of 150 seeds for each treatment of the five varieties from the twelve stations were planted in randomized eight-foot rows.

In experiments where definite numbers of seeds were used, emergence counts were made when the plants reached the two leaf stage. The percentage emergence was calculated by dividing the number of plants which emerged by the total number of seeds planted in each row.

Smut counts were made in each row of the various treatments. Stand counts were made when each row was fully headed, and the percentage of smut was calculated by dividing the number of smutted heads by the total stand count in each row.

In determining the species of smut present, small bits of each of ten smutted heads taken at random throughout the row were germinated on potato dextrose agar in Petri dishes. The smutted heads enclosed by a rather tough membrane and having smooth spores germinating with the presence of sporidia were considered to be Ustilago hordei. Those heads having echinulate spores and loose heads germinating with sporidia were considered to be Ustilago nigra, while those loose smutted heads having echinulate spores germinating without the presence of sporidia but long mycelial threads instead were considered to be Ustilago nuda. If, in a single row having more than ten smutted heads, there appeared to be more than a single species of smut present, then all the smutted heads were germinated. If, however, only a single species showed up in the germination of the ten heads taken at random, the remainder of the smutted heads were examined in the field. All emergence count, stand count, and smut count calculations were based on the average of the replications for each treatment.

EXPERIMENTAL RESULTS AND DISCUSSION

Description of the Barley Smuts

The three barley smuts, which make up a major portion of this study, are different in some very definite respects and are very much alike in others. Until comparatively recently the two loose smuts of barley had been quite confusing to most workers. Now, however, there are definite, accurate means of distinguishing one from the other. The covered smut of barley has never been much of a problem to differentiate from the other two species.

Ustilago hordei. This species of barley smut is commonly referred to as covered smut of barley and the name fits this disease very well. This smut has a tough protective membrane covering the smutted head which often does not break down until threshing time. This factor quite definitely restricts the spread of this species by wind or water, however, during the threshing operation one smutted head can serve to contaminate many normal heads and in this manner the covered smut has an effective way of propagating itself. Plate 1 shows different head types of Ustilago hordei. The heads are usually not as long or the culms as tall as healthy plants. The awns, while usually well developed, are not as long as awns on healthy heads. The smutted head often remains enclosed within the leaf sheath in this species and not at all infrequently is the peduncle twisted or kinked. This twisting and kinking is, no doubt, caused by the fact the head has difficulty emerging from the leaf sheath if it does succeed in coming out. The contents of the smutted head seem cemented together, and do not readily reduce to powder as do the loose

EXPLANATION OF PLATE I

U. hordei. Reading from left to right, healthy head; partially smutted head; fully smutted head with long awns; fully smutted head with moderate length awns; fully smutted head with slight awn development.

PLATE I

smuts. They are dark brown to black in color. When germinated in the laboratory with the use of potato dextrose agar, they always produce sporidia (usually four in number) on a rather short thick promycelium. The spores are entirely smooth, this coupled with the fact that they produce sporidia, definitely distinguish these species from the brown loose smut, and the fact the spores are smooth distinguishes it from the black loose smut, which has echinulate spores. This species can usually be distinguished from either of the loose smuts macroscopically by the fact it has the tough protective membrane over the smutted portion of the head, and the other general growth habits indicated previously. However, to remove any chance of error in identification, the microscopic method was employed.

Ustilago nigra. This species of barley smut is often referred to as black loose smut, and as the name indicates it is dark brownish black in color and is composed of a loose powdery mass of echinulate spores. Plate II shows different head types of this species of barley smut. From general observations, the awns tend to be more persistent and more fully developed than those of brown loose smut, although some heads have but slight awn development. Like the brown loose smut, the smutted heads usually are reduced in size but the culms average taller than those of normal heads. The contents of the smutted head are enclosed within a very thin membrane which breaks down easily and liberates the powdery mass of spores. Due to this loose powdery nature of the species it is readily transmitted by water or the spores carried far and wide by wind. Ordinarily by the time healthy heads are fully ripe, there is nothing but a bare rachis remaining of the smutted head. Unlike the covered smut, black

EXPLANATION OF PLATE II

U. nigra. Reading from left to right, healthy head; fully smutted head with long awns; fully smutted head with moderate length awns; fully smutted head with slight awn development.

PLATE II

loose smut heads are seldom retained within the leaf sheath and consequently the peduncles are usually not twisted or kinked. Black loose smut like covered smut of barley is of the seedling infection type and is carried over winter on the seed either on or within the glumes. Control of black loose smut as well as covered smut is not a serious problem as many of the chemical dusts, preferably a volatile type, will ordinarily give complete control.

Macroscopic identification of this species is much more difficult than the covered smut of barley. There are so many variations in types of smutted heads that there is no set rule by which they can be identified. The spores usually have a darker brownish black appearance than the brown loose smut, but this is often not an accurate determining factor. In the laboratory, however, the two loose smuts are quite easily separated. As previously stated, both have echinulate spores, but Ustilago nigra germinates by the production of sporidia on the promycelium which may bud and produce secondary sporidia. This difference is the main determining factor between the two loose smut species, as the brown loose smut never produces sporidia.

Ustilago nuda. This species of barley smut, commonly called brown loose smut, is quite similar in appearance to black loose smut. Both smuts are composed of a loose mass of powdery spores enclosed by a thin delicate membrane. The spores of brown loose smut, however, are lighter brown in color and have an olivaceous green appearance. The smutted heads usually completely emerge from the leaf sheaths and, like black loose smut, the average heads are smaller and the culms taller than those of healthy plants. Average heads of U. nuda ordinarily come out earlier than healthy

heads thus accomplishing floral infection, which is characteristic of this species. Due to the fact that the seeds of healthy heads are infected at the time of flowering, the smut will go unnoticed until seeds of these heads are planted and produce smutted heads. The hot-water treatment, previously described, is the only effective method of control for brown loose smut and it is not a practical method for the farmer. Plate III shows different head types of Ustilago nuda.

In view of the fact that both loose smuts of barley are similar in appearance, it is difficult and often impossible to distinguish one from the other, unless microscopic methods are employed. Both these species have echinulate spores, but upon germination the brown loose smut sends out a long slender thread of mycelium and does not produce sporidia. This is the main factor for distinguishing the two species of loose smut in the laboratory.

All three species of barley smut are common in Kansas, and most of the spring barley varieties commonly grown here are susceptible to them. Research is being carried on, however, to develop resistant varieties possessing good agronomic characters.

Plate IV illustrates the three species of barley smut, showing stages of disintegration of the smutted mass. All three species may infect the entire head or only portions of a head may be smutted.

EXPLANATION OF PLATE III

U. nuda. Reading from left to right, healthy head; partially smutted head; fully smutted head with long awns; fully smutted head with moderate length awns; fully smutted head with slight awn development.

PLATE III

EXPLANATION OF PLATE IV

Three barley smuts. Reading from left to right, healthy head; head of U. hordei; three heads of U. nuda, the first, smut mass still intact, second, smut mass breaking down, third, smutted portion gone and only bare rachis remaining; three heads of U. nigra, first smut mass still intact, second, smut mass breaking down, third, smutted portion gone and only bare rachis remaining.

PLATE IV

Chemical Seed Treatments

Hays Experiment Station Samples. The data on the effect of Spergon and New Improved Ceresan on the emergence of spring barley are presented in Table 1. In the first planting there was an increase of one percent emergence with the use of Spergon over the untreated seed, however, in the second planting with the use of Spergon there was no appreciable difference. With New Improved Ceresan as the chemical used, there was an average increase of three percent emergence over the untreated seed in the first planting, while in the second planting there was an even more significant increase of six percent average emergence over the untreated seed. These data were not in agreement with those of Livingston (1947).

Climatic conditions present when this experiment and the following experiments were planted, no doubt, played an important role in the differences obtained in percentages of emergence and smut between different plantings of the same material. Since that was not part of this study it will only be mentioned as the data were too incomplete to draw any accurate conclusion on this subject. Weather conditions following the first date of planting (March 26, 1947) were cool and cloudy, rain and snow both coming during the period from planting to date of emergence on April 5, 1947. Weather conditions following the second date of planting (May 3, 1947) were clear, warm and dry from time of planting to date of emergence on May 10, 1947. Weather conditions were clear, hot and dry following the fall planting (October 11, 1947) until the plants emerged on October 17, 1947. Weather conditions were clear, warm, and very dry following the 1948 planting (March 29, 1948) until time of emergence of

Table 1. Effect of chemical seed treatments on emergence of spring barley.[1] Manhattan, Kansas. 1947.

Year	Variety	Percent germination[2]	Percent Emergence					
			First Planting[3]			Second Planting[4]		
			Untreated	Spergon	New Improved Ceresan	Untreated	Spergon	New Improved Ceresan
1941	Beecher	84.00	74.50	74.40	76.20	66.50	65.80	72.10
1946	Beecher	90.00	87.10	88.40	90.20	77.50	75.50	79.00
1941	Flynn	94.00	85.00	86.30	87.30	79.10	78.50	77.10
1946	Flynn	91.00	84.10	86.70	87.30	74.10	72.00	70.80
1941	Spartan	89.00	72.50	70.40	80.90	62.00	60.70	82.00
1946	Spartan	95.00	86.20	88.90	86.70	69.20	74.70	82.10
Mean		90.50	81.57	82.52	84.77	71.40	71.20	77.18

1 Five replications of 200 seeds each.
2 Germination tests run by Kansas State Seed Laboratory, May 2, 1947.
3 Planted March 26, 1947.
4 Planted May 3, 1947.

the plants on April 4, 1948.

Table 2 contains data on the percentage smut from the untreated samples and samples treated with Spergon and New Improved Ceresan. There was no significant difference in the amount of smut present in the treated and the untreated samples, except what may be accounted for due to natural variation. Another factor to be considered is that the majority of smut present was brown loose smut which is not controlled by Spergon and New Improved Ceresan.

Farmers' samples. Table 3 shows the farmers' samples by county and variety, with the amount of smut present in each sample using various chemical seed treatments, for the two 1947 spring plantings. As indicated in this table, many farmers are misinformed as to the variety of spring barley they are growing. Inasmuch as the majority of the smut present in these samples was U. nuda, there was no significant difference in the amount of smut present in the untreated samples and those treated with Spergon and New Improved Ceresan. Plate V gives the distribution by counties of the 62 farmers' samples used in the 1947 plantings and also gives the percentage and species of smut present in each sample. The majority of the samples in this experiment were received from farmers in the central portion of the state. The reason for this distribution is that the main barley section of Kansas includes the central and western counties, but the greater distance of the latter from the facilities of the Kansas State Seed Laboratory, results in fewer samples being received. There was no significant difference in the distribution of the three species of smut throughout the state, however, samples from the extreme western portion and those from the extreme eastern portion of the state

Table 2. Effect of chemical seed treatments on brown loose smut of spring barley.[1] Manhattan, Kansas. 1947.

Year	Variety	Percent Smut					
		First Planting[2]			Second Planting[3]		
		Untreated	Spergon	New Improved Ceresan	Untreated	Sperson	New Improved Ceresan
1941	Beecher	16.68	13.56	13.82	11.84	11.53	14.95
1946	Beecher	7.62	7.71	11.49	6.04	7.05	8.40
1941	Flynn	5.96	4.88	6.57	2.89	3.72	6.73
1946	Flynn	7.44	6.71	4.94	4.95	5.38	5.75
1941	Spartan	1.88	1.98	1.98	1.71	0.99	2.93
1946	Spartan	0.51	0.65	1.32	1.00	0.72	0.24
Mean		6.68	5.92	6.69	4.74	4.90	6.50

1 Five replications of 200 seeds each.
2 Planted March 26, 1947.
3 Planted May 3, 1947.

Table 3. Smut data on farmers' samples of spring barley. Manhattan, Kansas. 1947.

Row No.	County	Farmers' variety name	True variety	Percent Smut					
				First Planting[1]			Second Planting[2]		
				Untreated	Spergon	New Improved Ceresan	Untreated	Spergon	New Improved Ceresan
1	Harvey	Flynn	Flynn	10.47	4.36	6.38	8.17	7.10	7.80
2	Riley	Flynn	Flynn	8.07	4.69	2.23	7.75	3.52	3.14
3	Butler	Flynn	Flynn	2.05	5.65	0.00	5.66	0.60	2.77
4	Mitchell	Flynn	Flynn	9.56	5.07	7.00	2.91	3.61	5.45
5	Phillips	Flynn	Stavropol	0.34	0.00	0.00	0.00	0.00	0.00
6	Ellsworth	Flynn	Flynn	4.60	1.15	0.83	7.95	0.00	0.00
7	Barton	Flynn	Flynn	1.32	0.00	0.00	1.37	0.00	0.48
8	Barton	Flynn	Flynn	3.55	0.00	0.00	0.46	0.00	0.00
9	Dickinson	Flynn	Flynn	16.30	11.25	9.35	10.78	3.48	5.11
10	Clark	Flynn	Stavropol	1.98	1.11	1.93	1.85	1.45	0.76
11	Kiowa	Flynn	Mixed Flynn	3.07	0.00	0.83	0.51	1.36	2.39
12	Reno	Flynn	Flynn	4.60	5.00	6.89	6.06	2.32	4.39
13	Reno	Flynn	Trebi	0.00	0.00	0.00	0.00	0.00	0.00
14	Sumner	Flynn	Flynn	1.10	5.04	2.02	0.00	2.88	1.78
15	Ness	Flynn	Flynn	0.62	0.72	0.83	1.02	2.48	1.00
16	Clark	Flynn	Flynn	6.78	9.34	11.11	7.27	7.20	7.02
17	Sumner	Flynn	Flynn	12.75	20.52	16.50	11.73	11.64	12.57
18	Russell	Flynn	Flynn	1.75	0.00	0.00	0.00	0.41	0.00
19	Norton	Flynn	Flynn	4.82	5.39	6.58	2.31	1.66	1.84
20	Stafford	Beecher	Beecher	0.00	0.00	0.00	0.00	0.45	0.00
21	Riley	Beecher	Beecher	12.69	12.24	13.61	14.66	13.93	10.10
22	Ellsworth	Beecher	Beecher	1.04	1.01	1.03	0.71	0.55	0.00
23	Norton	Spartan	Spartan	2.23	0.00	1.11	4.37	0.63	0.64
24	Clay	Iowa	Mixed Spartan	9.18	2.71	4.71	3.96	2.81	3.44
25	Reno	No name	Stavropol	2.42	0.00	0.00	2.17	1.73	0.00
26	Wallace	No name	Trebi	0.00	0.00	0.00	0.00	0.00	0.00
27	Jewell	No name	Flynn	0.00	2.65	2.15	0.00	2.04	0.58
28	Kingman	No name	Flynn	13.79	4.00	5.30	3.70	2.87	4.52
29	Russell	No name	Flynn	6.11	0.00	1.56	2.66	0.00	0.00

Table 3. (cont.).

Row No.	County	Farmers' variety name	True variety	Percent Smut					
				First Planting			Second Planting		
				Untreated	Spergon	New Improved Ceresan	Untreated	Spergon	New Improved Ceresan
30	Osborne	No name	Stavropol	0.00	0.00	0.00	0.00	0.00	0.00
31	Cheyenne	No name	Spartan	2.90	1.00	0.80	1.49	0.00	0.59
32	Haskell	No name	Stavropol	1.66	1.20	0.00	0.00	0.00	0.00
33	Lane	No name	Flynn	0.36	1.09	0.76	0.00	1.00	1.69
34	Ellis	No name	Spartan	4.87	2.73	4.56	2.46	3.70	2.97
35	Finney	No name	Stavropol	9.44	5.34	5.51	5.64	5.51	4.82
36	Ellsworth	No name	Flynn	0.86	0.36	1.75	1.25	1.75	0.00
37	Edwards	No name	Flynn	1.65	0.00	0.36	0.78-	0.00	0.00
38	Marshall	No name	Beecher	3.06	0.00	0.00	1.12	0.00	0.00
39	Pawnee	No name	Flynn	9.41	5.82	0.00	4.14	1.50	3.30
40	Linn	No name	Beecher	30.17	27.86	28.99	25.98	21.71	21.81
41	Morris	No name	Flynn	0.81	0.40	5.07	2.76	0.00	5.98
42	Butler	No name	Stavropol	13.76	9.89	6.34	3.66	1.20	10.57
43	Marshall	No name	Mixed Flynn & Trebi	0.00	0.00	0.00	0.00	0.00	0.00
44	Wabaunsee	No name	Flynn	12.21	4.36	3.25	0.88	5.88	3.89
45	Clark	No name	Flynn	4.24	5.42	2.75	1.68	2.70	2.00
46	Gove	No name	Flynn	9.59	3.94	5.20	2.48	5.69	0.95
47	Osborne	No name	Beecher	17.81	14.11	15.56	13.61	10.00	4.49
48	Kingman	No name	Flynn	11.97	9.35	10.64	7.22	7.42	2.24
49	Osborne	No name	Stavropol	0.00	0.00	0.00	0.00	0.00	0.00
50	Cherokee	No name	Beecher	4.59	0.35	1.32	0.00	1.50	0.00
51	Russell	No name	Stavropol	7.74	0.71	0.00	1.95	0.37	0.00
52	Jewell	No name	Mixed Trebi & Spartan	8.95	4.85	3.03	6.86	4.76	0.00
53	Hodgeman	No name	Spartan	0.38	0.00	0.00	0.58	0.00	3.07
54	Gray	No name	Flynn	0.31	0.78	0.00	1.36	0.38	0.00
55	Rooks	No name	Stavropol	1.67	0.00	0.00	0.71	0.00	0.00
56	Pratt	No name	Stavropol	5.16	0.00	0.71	0.00	0.00	0.00

Table 3. (concl.).

Row No.	County	Farmers' variety name	True variety	Percent Smut					
				First Planting			Second Planting		
				Untreated	Spergon	New Improved Ceresan	Untreated	Spergon	New Improved Ceresan
57	Lane	No name	Flynn	3.44	0.36	0.00	1.70	0.00	0.00
58	Russell	Flynn	Flynn	10.09	0.00	1.10	3.46	0.49	0.00
59	Smith	Flynn	Flynn	8.97	6.10	8.68	12.50	7.87	1.68
60	Sheridan	Flynn	Flynn	6.84	2.64	10.80	6.48	8.87	1.07
61	Sherman	Pearl Barley	Spartan	0.00	0.00	0.40	0.00	0.89	0.00
62	Pt. Collins, Colo.	Trebi	Trebi	0.00	0.00	0.00	0.00	0.00	0.00

1 Planted March 26, 1947.
2 Planted May 3, 1947.

EXPLANATION OF PLATE V

Distribution of farmers' samples of spring barley used in first planting 1947. Figures indicate percentage smut in each barley sample.

o - sample with no smut.

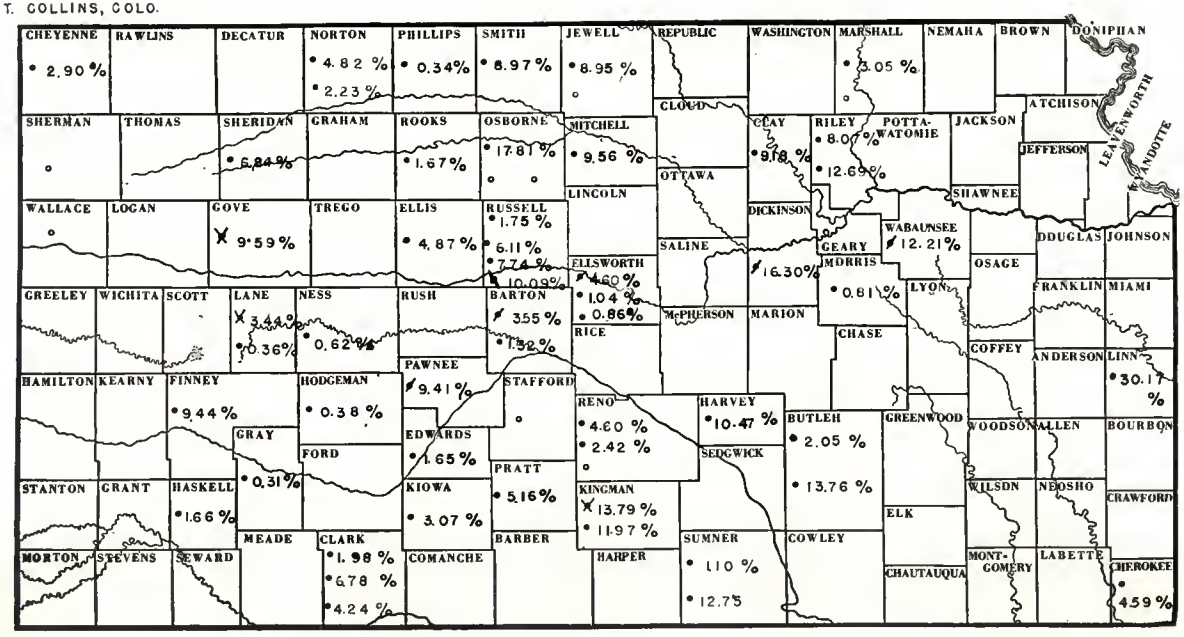
• - sample with U. nuda.

 - sample with U. nuda and U. hordei.

 - sample with U. nuda and U. nigra.

 - sample with U. nuda, U. nigra, and U. hordei.

PLATE V


FT. COLLINS, COLO.
CHEYENNE
• 2.90 %
RAWLINS
DECATUR
NORTON
• 4.82 %
• 2.23 %
PHILLIPS
• 0.34%
SMITH
• 8.97 %
JEWELL
• 8.95 %
REPUBLIC
WASHINGTON
MARSHALL
• 3.05 %
NEMAHA
BROWN
DONIPHAN
ATCHISON
SHERMAN
THOMAS
SHERIDAN
• 6.84%
GRAHAM
ROOKS
• 1.67%
OSBORNE
• 17.81 %
MITCHELL
• 9.56 %
CLOUD
CLAY
• 9.18 %
RILEY
• 8.07 %
• 12.69 %
POTTA-WATOMIE
JACKSON
JEFFERSON
LEAVENWORTH
WYANDOTTE
OTTAWA
WALLACE
LOGAN
GOVE
X 9.59%
TREGO
ELLIS
• 4.87 %
RUSSELL
• 1.75 %
• 6.11 %
• 7.74 %
• 10.09%
LINCOLN
ELLSWORTH
• 4.60 %
• 1.04 %
• 0.86%
SALINE
DICKINSON
• 16.30%
GEARY
MORRIS
• 0.81 %
WABAUNSEE
• 12.21%
SHAWNEE
DOUGLAS
JOHNSON
OSAGE
LYON
GREELEY
WICHITA
SCOTT
LANE
X 3.44%
• 0.36%
NESS
• 0.62 %
RUSH
BARTON
• 3.55 %
• 1.52 %
RICE
McPHERSON
MARION
CHASE
FRANKLIN
MIAMI
COFFEY
ANDERSON
LINN
• 30.17 %
HAMILTON
KEARNY
FINNEY
• 9.44 %
HODGEMAN
• 0.38 %
PAWNEE
• 9.41 %
STAFFORD
RENO
• 4.60 %
• 2.42 %
HARVEY
• 10.47 %
BUTLER
• 2.05 %
• 13.76 %
GREENWOOD
WOODSON
ALLEN
BOURBON
GRAY
• 0.31 %
FORD
EDWARDS
• 1.65 %
SEDGWICK
STANTON
GRANT
HASKELL
• 1.66 %
KIOWA
• 3.07 %
PRATT
• 5.16%
KINGMAN
X 13.79 %
• 11.97 %
ELK
WILSON
NEOSHO
CRAWFORD
MEADE
CLARK
• 1.98 %
• 6.78 %
• 4.24 %
BARBER
COMANCHE
HARPER
SUMNER
• 1.10 %
• 12.75
COWLEY
CHAUTAUQUA
MONT-GOMERY
LABETTE
CHEROKEE
• 4.59 %
MORTON
STEVENS
SEWARD

contained only U. nuda. With exception of the sample received from Linn County, in the eastern tier of counties, which was heavily infected with smut, there was no significant difference in the percentage of smut from the various other counties. Table 4 presents data on farmers' samples by county and variety, with the amount of smut present in each sample with the use of chemical seed treatments for the 1948 spring planting. The samples used in this planting were entirely different from those of the 1947 plantings, but in this planting like the 1947 plantings, many of the farmers' varietal designations were incorrect.

Plate VI gives the distribution of the 52 farmers' samples used in the 1948 planting. This planting, like the 1947 plantings, showed no significant difference in the amount or species of smut present in the various counties of Kansas represented. Inasmuch as the smut present in the samples of this planting were mainly of the species U. nuda, there was no significant difference in the amount of smut present in the untreated samples and those treated with Spergon and New Improved Ceresan.

Table 5 shows the percentage smut by species for each variety of spring barley used in the two 1947 plantings and the 1948 planting. The percentages of U. hordei and U. nigra were comparatively small in the untreated samples. This is, no doubt, due to the fact that farmers in general treat their seed barley with chemical seed treatments for the control of these two species of smut. Satisfactory control can be accomplished by the use of chemical seed treatments for combating U. hordei and U. nigra as shown by Table 5, where there were but three exceptions of Spergon not giving complete control for these two species of smut and New Improved Ceresan proving entirely adequate in controlling these two species. Varietal differences as to the presence of smut in the farmers' samples

Table 4. Smut data on farmers' samples of spring barley.[1] Manhattan, Kansas. 1948.

Row No.	County	Farmers' variety name	True variety	Percent Smut		
				Untreated	Spergon	New Improved Ceresan
1	Pawnee	Flynn	Stavropol	1.38	2.26	0.00
2	Republic	Flynn	Flynn	5.02	2.91	0.79
3	Rush	Flynn	Stavropol	5.17	5.98	3.38
4	Russell	Flynn	Flynn	0.91	4.15	0.00
5	Jewell	Flynn	Club Mariout	0.33	0.79	0.40
6	Kiowa	Flynn	Flynn	0.00	0.00	0.00
7	Jewell	Flynn	Beecher	1.84	0.00	1.96
8	Ness	Flynn	Flynn	1.96	0.00	0.00
9	Lincoln	Flynn	Flynn	1.27	0.66	0.00
10	Ness	Flynn	Flynn	0.00	0.66	0.00
11	Ness	Flynn	Flynn	0.00	0.33	0.00
12	Clark	Flynn	Spartan	0.47	0.33	0.00
13	Clark	Flynn	Flynn	0.99	2.51	0.50
14	Dickinson	Flynn	Flynn	8.38	10.71	11.24
15	Graham	Flynn	Flynn	2.70	1.23	1.32
16	Ness	Flynn	Flynn	1.41	0.00	0.00
17	Morris	Flynn	Flynn	3.74	4.11	0.99
18	Trego	Flynn	Flynn	0.83	0.28	0.50
19	Stafford	Beecher	Beecher	0.71	1.72	0.79
20	Jewell	Beecher	Flynn	1.72	0.00	0.00
21	Osborne	Spartan	Spartan	4.99	1.09	0.00
22	Osborne	Spartan	Spartan	4.76	1.72	1.32
23	Ellis	Spartan	Spartan	0.00	0.66	0.00
24	Smith	Spartan	Spartan	3.75	1.32	2.28
25	Rush	Spartan	Spartan	1.52	0.79	1.19
26	Mitchell	Spartan	Spartan	2.78	0.99	1.64
27	Lincoln	Spartan	Spartan	3.85	1.23	0.00
28	Smith	Spartan	Spartan	0.95	0.57	0.00
29	Lincoln	Merit Club	Club Mariout	0.00	0.00	0.00
30	Lincoln	Merit Club	Club Mariout	0.00	0.00	0.00

Table 4. (concl.).

Row No.	County	Farmers' variety name	True variety	Percent Smut		
				Untreated	Spergon	New Improved Ceresan
31	Lincoln	Merit Club	Club Mariout	0.00	0.00	0.00
32	Stratton, Neb.	Club Mariout	Club Mariout	1.29	0.00	0.00
33	Ellis	Club barley	Club Mariout	0.00	0.00	0.57
34	Riley	Mansing	Mansing	0.00	1.19	0.00
35	Haskell	No name	Spartan	1.23	1.39	0.00
36	Gove	No name	Flynn	5.06	6.67	0.79
37	Ford	No name	Flynn	0.62	0.99	0.00
38	Pawnee	No name	Flynn	0.84	5.66	3.47
39	Barber	No name	Beecher	4.90	5.96	3.85
40	Barton	No name	Stavropol	0.00	0.00	0.00
41	Clay	No name	Spartan	0.28	1.39	0.00
42	Edwards	No name	Flynn	1.13	2.68	0.00
43	Ellsworth	No name	Stavropol	0.00	0.00	0.00
44	Washington	No name	Stavropol	0.57	0.33	0.00
45	Logan	No name	Flynn	1.48	2.78	0.66
46	Pratt	No name	Club Mariout	0.00	0.00	0.00
47	Sheridan	No name	Flynn	2.68	5.06	1.19
48	Sherman	No name	Spartan	1.15	0.40	0.00
49	Riley	No name	Spartan	1.60	2.60	0.00
50	Republic	No name	Spartan	0.99	0.25	0.00
51	Rawlins	No name	Stavropol	1.48	0.99	0.00
52	Wichita	Beecher	Beecher	0.00	0.00	0.00

1 Planted March 29, 1948.

EXPLANATION OF PLATE VI

Distribution of farmers' samples of spring barley used in 1948 planting. Figures indicate percentage smut in each barley sample.

o - sample with no smut.

• - sample with *U. nuda*.

/ - sample with *U. hordei*.

⌿ - sample with *U. nuda* and *U. hordei*.

\ - sample with *U. nuda* and *U. nigra*.

X - sample with *U. nuda*, *U. nigra*, and *U. hordei*.

PLATE VI

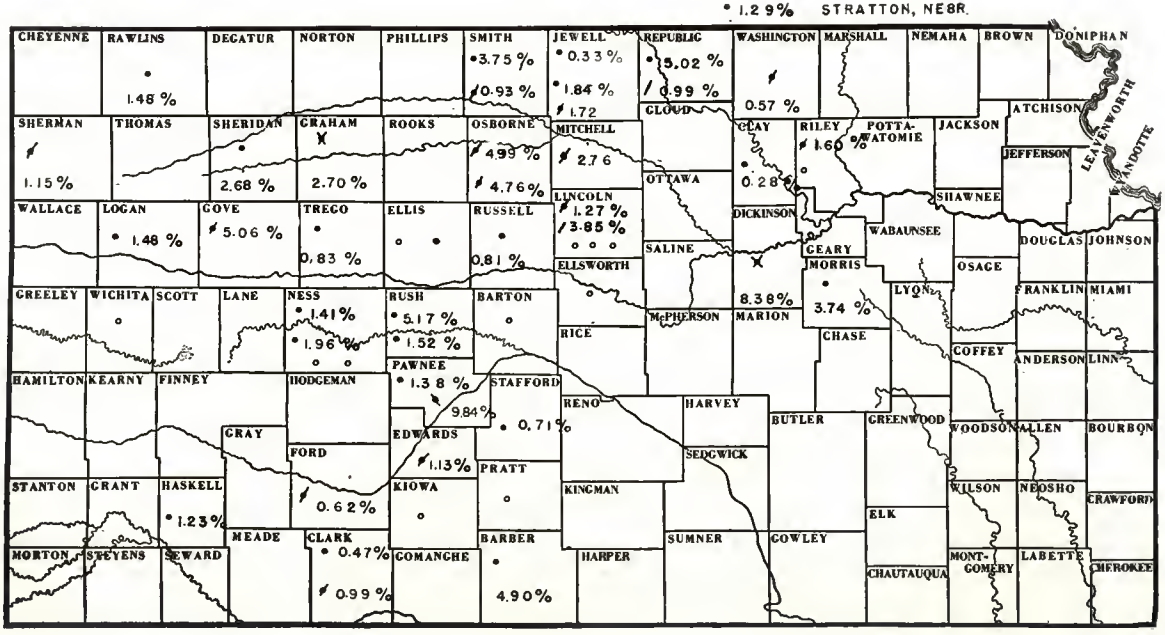

1.29% STRATTON, NEBR.
CHEYENNE
RAWLINS
1.48 %
DECATUR
NORTON
PHILLIPS
SMITH
3.75 %
0.93 %
JEWELL
0.33 %
1.84 %
1.72
REPUBLIC
3.02 %
0.99 %
WASHINGTON
0.57 %
MARSHALL
NEMAHA
BROWN
DONIPHAN
ATCHISON
LEAVENWORTH
WYANDOTTE
SHERMAN
1.15 %
THOMAS
SHERIDAN
2.68 %
GRAHAM
2.70 %
ROOKS
OSBORNE
4.99 %
4.76 %
MITCHELL
2.76
CLOUD
CLAY
0.28 %
RILEY
1.60 %
POTTAWATOMIE
JACKSON
JEFFERSON
OTTAWA
LINCOLN
1.27 %
3.85 %
SHAWNEE
WALLACE
LOGAN
1.48 %
GOVE
5.06 %
TREGO
0.83 %
ELLIS
RUSSELL
0.81 %
DICKINSON
WABAUNSEE
DOUGLAS
JOHNSON
SALINE
GEARY
ELLSWORTH
MORRIS
3.74 %
OSAGE
LYON
FRANKLIN
MIAMI
GREELEY
WICHITA
SCOTT
LANE
NESS
1.41 %
1.96 %
RUSH
5.17 %
1.52 %
BARTON
McPHERSON
MARION
8.38%
CHASE
COFFEY
ANDERSON
LINN
RICE
HAMILTON
KEARNY
FINNEY
HODGEMAN
PAWNEE
1.38 %
9.84%
STAFFORD
0.71%
RENO
HARVEY
BUTLER
GREENWOOD
WOODSON
ALLEN
BOURBON
GRAY
EDWARDS
SEDGWICK
FORD
1.13%
PRATT
STANTON
GRANT
HASKELL
1.23%
0.62%
KIOWA
KINGMAN
ELK
WILSON
NEOSHO
CRAWFORD
MEADE
CLARK
0.47%
0.99%
COMANCHE
BARBER
4.90%
HARPER
SUMNER
COWLEY
MONTGOMERY
LABETTE
CHEROKEE
MORTON
STEVENS
SEWARD
CHAUTAUQUA

Table 5. Precentage smut in farmers' samples of spring barley in Kansas.

Variety	Number of samples	Untreated			Spergon			New Improved Ceresan		
		hordei	nuda	nigra	hordei	nuda	nigra	hordei	nuda	nigra
Planted March 26, 1947										
Flynn	33	0.83	4.79	0.18	0	3.83	0	0	3.94	0
Beecher	7	0.00	9.91	0.00	0	7.94	0	0	8.68	0
Stavropol	11	0.00	4.02	0.00	0	1.66	0	0	1.32	0
Spartan	6	0.00	3.26	0.00	0	1.07	0	0	1.86	0
Trebi[1]	3	0.00	0.00	0.00	0	0.00	0	0	0.00	0
Mixed Trebi and Spartan	1	0.00	8.95	0.00	0	4.85	0	0	3.03	0
Mixed Trebi and Flynn	1	0.00	0.00	0.00	0	0.00	0	0	0.00	0
Planted May 3, 1947										
Flynn	33	0.62	2.80	0.45	0	2.90	0.04	0	2.53	0
Beecher	7	0.16	7.85	0.00	0	6.88	0.00	0	5.20	0
Stavropol	11	0.28	1.06	0.06	0	0.93	0.00	0	1.47	0
Spartan	6	0.56	1.58	0.00	0	1.34	0.00	0	1.79	0
Trebi[1]	3	0.00	0.00	0.00	0	0.00	0.00	0	0.00	0
Mixed Trebi and Spartan	1	0.00	6.86	0.00	0	4.76	0.00	0	0.00	0
Mixed Trebi and Flynn	1	0.00	0.00	0.00	0	0.00	0.00	0	0.00	0
Planted March 29, 1948										
Flynn	20	0.30	2.10	0.09	0.01	2.56	0	0	1.07	0
Beecher	4	0.00	1.86	0.00	0.00	1.93	0	0	1.65	0
Stavropol	6	0.05	1.39	0.00	0.00	1.59	0	0	0.56	0
Spartan	14	0.70	1.32	0.00	0.06	0.99	0	0	0.46	0
Club Mariout[2]	7	0.00	0.23	0.00	0.00	0.11	0	0	0.14	0
Munsing	1	0.00	0.00	0.00	0.00	1.19	0	0	0.00	0

1 One sample from Ft. Collins, Colorado.
2 One sample from Stratton, Nebraska.

as indicated in Table 5, show that Beecher had a higher infection of U. nuda in the 1947 plantings but no significant differences were visible in the 1948 planting. The data indicate that the variety Trebi is somewhat resistant to smut. Moore (1936) and Livingston (1947) had similar results. The data also indicate that Beecher is not so susceptible to infections of U. hordei and U. nigra, while on the other hand, Flynn seems to be equally susceptible to all three species of smut.

Hot Water Treatment

Hays Experiment Station Samples. Table 6 gives the effect of hot-water treatment on emergence of spring barley from three plantings in 1947. The variations in the different plantings within the same variety can, no doubt, be attributed to the environment because these three plantings were made under quite different climatic conditions. As Table 6 indicates, there was a significant difference in the injurious effect of the hot-water treatment on the emergence of the different varieties. Beecher showed the greatest injury, Flynn showed a lesser amount of injury and Flynn x Vaughn cross showed the least injury. The five hour pre-soaking period followed by the regular hot-water treatment was quite severe in its effect on the emergence. The four and three hour presoaking periods were materially less in their injurious effects but they decreased the emergence decidedly. There was no significant difference in the two hour, one hour and no presoaking periods, either compared with one another or with the untreated samples.

Table 7 shows the effect of hot-water treatment on brown loose smut in spring barley. No smut was present in any of the three varieties with

Table 6. Effect of hot-water treatment on emergence of spring barley.[1] Manhattan, Kansas. 1947.

Variety	Percent germination[2]	Treatment[3]	Percent Emergence: First Planting[4]	Second Planting[5]	Third Planting[6]
Beecher		5 hrs.	30.60	33.00	21.20
Flynn		5 hrs.	61.70	52.80	40.60
Flynn x Vaughn		5 hrs.	69.90	66.30	57.20
Mean			54.07	50.70	39.66
Beecher		4 hrs.	30.40	32.30	24.20
Flynn		4 hrs.	65.60	61.20	46.50
Flynn x Vaughn		4 hrs.	79.20	78.90	67.10
Mean			58.40	56.80	45.93
Beecher		3 hrs.	52.10	58.30	44.40
Flynn		3 hrs.	69.80	63.70	57.80
Flynn x Vaughn		3 hrs.	82.40	83.10	76.70
Mean			68.10	68.37	59.63
Beecher		2 hrs.	77.70	75.20	67.10
Flynn		2 hrs.	78.00	72.40	61.30
Flynn x Vaughn		2 hrs.	88.30	83.20	73.40
Mean			81.33	76.93	67.27
Beecher		1 hr.	82.50	73.30	68.30
Flynn		1 hr.	81.10	66.60	64.00
Flynn x Vaughn		1 hr.	90.80	80.60	76.20
Mean			84.80	73.50	69.50
Beecher		0 hr.	87.20	76.80	68.80
Flynn		0 hr.	78.10	70.60	69.70
Flynn x Vaughn		0 hr.	88.80	83.20	74.60
Mean			84.70	76.87	67.70
Beecher	90.00	Untreated	90.80	77.90	74.00
Flynn	91.00	Untreated	79.90	73.40	66.80
Flynn x Vaughn	96.00	Untreated	91.70	85.20	80.20
Mean	92.33		87.40	78.83	73.67

1 Five replications of 200 seeds each.
2 Germination tests run by Kansas State Seed Laboratory, May 2, 1947.
3 Five hours, 4 hours, 3 hours, 2 hours, 1 hour and 0 hour designate periods of presoaking followed by regular hot-water treatment.
4 Planted March 26, 1947.
5 Planted May 3, 1947.
6 Planted October 11, 1947.

Table 7. Effect of hot-water treatment on brown loose smut in spring barley.[1] Manhattan, Kansas. 1947.

Variety	Treatment[2]	Percent Smut	
		First Planting[3]	Second Planting[4]
Beecher	5 hrs.	0.00	0.00
Flynn	5 hrs.	0.00	0.00
Flynn x Vaughn	5 hrs.	0.00	0.00
Mean		0.00	0.00
Beecher	4 hrs.	0.00	0.00
Flynn	4 hrs.	0.00	0.00
Flynn x Vaughn	4 hrs.	0.00	0.00
Mean		0.00	0.00
Beecher	3 hrs.	0.00	0.00
Flynn	3 hrs.	0.10	0.00
Flynn x Vaughn	3 hrs.	0.53	0.44
Mean		0.21	0.15
Beecher	2 hrs.	1.43	0.69
Flynn	2 hrs.	1.38	0.78
Flynn x Vaughn	2 hrs.	1.81	3.56
Mean		1.54	1.68
Beecher	1 hr.	5.95	5.01
Flynn	1 hr.	5.54	2.33
Flynn x Vaughn	1 hr.	5.13	4.85
Mean		5.54	4.06
Beecher	0 hr.	7.51	5.40
Flynn	0 hr.	5.90	5.11
Flynn	0 hr.	7.88	5.23
Mean		7.09	5.25
Beecher	Untreated	8.78	6.40
Flynn	Untreated	4.78	3.17
Flynn x Vaughn	Untreated	7.31	6.81
Mean		6.96	5.46

1 Five replications of 200 seeds each.
2 Five hours, 4 hours, 3 hours, 2 hours, 1 hour and 0 hour designate periods of presoaking followed by regular hot-water treatment.
3 Planted March 26, 1947.
4 Planted May 3, 1947.

either the five-hour or four-hour presoaking periods followed by the regular hot-water treatment. There was a slight amount of smut present in the three-hour presoaking period. In the two-hour, one-hour and no presoaking periods there was a definite increase in smut with the decrease in the amount of presoaking time. There was no significant difference in the amount of smut present in the one-hour presoak, no presoak and untreated samples. Smut is apparently killed easier by the hot-water treatment in Beecher than the other varieties. This fact is illustrated in Table 7 where the three-hour presoak period destroyed all the smut in Beecher but a small percentage of smut was present in each of the other varieties. Beecher, however, showed a greater degree of injury to germination by the use of hot-water treatments than did the other varieties.

Farmers' Samples. Table 8 shows the effect of hot-water treatment on emergence and brown loose smut in farmers' samples of spring barley. This experiment is somewhat different than the previous experiment in that all the samples used were of the variety Beecher, and all were old seeds, having been produced in 1941. This table shows that there was a significant decline in the percentage germination as the presoaking periods were increased. Percentage smut likewise decreased as the presoaking periods were lengthened. In this manner, there is a definite correlation between the amount of smut present and the length of the presoaking period previous to the regular hot-water treatment. The data in this table agree with the data in the preceding table in that there was no smut in Beecher for the three-hour presoaking period in either case. Neither in this experiment nor in the one preceding is there any correlation between the amount of injury received and the percentage germination before the seeds were treated.

Table 8. Effect of hot-water treatment on emergence and brown loose smut of spring barley.[1] Manhattan, Kansas. 1947.

Barley Designation[2]	Percent germination[3]	Treatment[4]	Percent Emergence	Percent Smut
Colby		5 hrs.	13.60	0.00
Jansonius		5 hrs.	5.40	0.00
Kindler		5 hrs.	3.40	0.00
Mahoney		5 hrs.	1.50	0.00
Mean			5.98	0.00
Colby		3 hrs.	27.80	0.00
Jansonius		3 hrs.	12.30	0.00
Kindler		3 hrs.	11.10	0.00
Mahoney		3 hrs.	12.30	0.00
Mean			15.88	0.00
Colby		1 hr.	32.60	6.87
Jansonius		1 hr.	19.40	13.00
Kindler		1 hr.	16.50	0.12
Mahoney		1 hr.	24.30	6.60
Mean			23.20	6.65
Colby	85.00	Untreated	75.90	20.90
Jansonius	89.00	Untreated	51.10	27.98
Kindler	82.00	Untreated	41.50	6.00
Mahoney	90.00	Untreated	64.60	13.38
Mean	86.50		58.28	17.07

1 Five replications of 200 seeds each planted March 26, 1947.
2 Seecher grown in 1941 by individual farmers.
3 Germination tests run by seed laboratory May 2, 1947.
4 Five hours, 3 hours and 1 hour designate period of presoaking followed by regular hot-water treatment.

Experiment Stations' Samples. Table 9 gives the percentages of Ustilago nuda and emergence of spring barley using hot-water treatments. These data are based on results from five varieties of spring barley grown at 12 experiment stations in central and western United States. Plate VII gives the geographical locations of these 12 stations. Table 9 also presents data on the weight of the seeds used in this experiment, the moisture content at time of treatment and the percentage germination as determined by the Kansas State Seed Laboratory. There is no significant correlation among these various factors and the injury caused by the hot-water treatment or the percentage of smut present in the various varieties. The data giving the percentage smut in these samples were based on the presence of U. nuda, with but three exceptions, in which U. hordei and U. nigra were present in small amounts as noted in Table 9.

Plate VIII presents in graphic form data on the emergence of the various varieties when the hot-water treatment was used. There was no significant difference in the percentage emergence of the five varieties in the untreated samples but there was a definite difference in the degree of injury suffered by the varieties in the case of the severe hot-water treatments. The variety Atlas from the station at Lind, Washington, received the greatest injury. Beecher was injured the greatest, considering the 12 stations as a whole. There is no known explanation for this inter-varietal difference in injury. The subject of environment has been proposed as an explanation, but that hardly seems likely in view of the fact that two widely separated stations with apparently entirely different climatic conditions, Lind, Washington, and Colby, Kansas, gave similar results while those stations much closer and seemingly having more nearly

Table 9. Percentages of emergence and of Ustilago nuda in spring barley.[1]

Variety	Hot-water treatment	Wt. in grams of 100 seeds	Moisture[2]	Germination[3]	Emergence	Smut
			Percent			
Hays, Kansas						
Atlas	Untreated	3.56	8.79	94	88.66	15.92
	3 hrs.[4]				85.00	1.21
	5 hrs.				81.50	0.00
Pesbar	Untreated	3.57	8.71	98	92.33	4.68
	3 hrs.				88.16	0.90
	5 hrs.				88.00	0.00
Flynn	Untreated	3.69	8.56	93	91.66	5.82[5]
	3 hrs.				87.50	2.14
	5 hrs.				83.33	0.00
Beecher	Untreated	3.93	8.53	95	90.33	28.80
	3 hrs.				86.83	2.89
	5 hrs.				55.33	0.00
Spartan	Untreated	3.92	8.81	96	91.16	8.67
	3 hrs.				82.00	2.19
	5 hrs.				78.50	0.00
Colby, Kansas						
Atlas	Untreated	3.32	7.68	93	83.66	1.46
	3 hrs.				75.50	0.00
	5 hrs.				56.50	0.00
Pesbar	Untreated	3.07	7.79	98	89.66	0.71
	3 hrs.				86.66	0.00
	5 hrs.				80.83	0.00
Beecher	Untreated	3.85	7.80	97	87.66	7.54
	3 hrs.				77.50	0.39
	5 hrs.				30.66	0.00
Spartan	Untreated	3.99	7.89	97	91.00	2.53[5]
	3 hrs.				80.66	0.92
	5 hrs.				72.66	0.00
Lincoln, Nebraska						
Atlas	Untreated	3.66	9.24	90	84.00	6.27

Table 9. (cont.).

Variety	Hot-water treatment	Wt. in grams of 100 seeds	Percent Moisture	Germination	Emergence	Smut
	3 hrs.				77.00	3.31
	5 hrs.				70.50	0.00
Feebar	Untreated	3.49	7.57	96	88.33	2.74
	3 hrs.				93.16	0.78
	5 hrs.				81.66	0.00
Flynn	Untreated	3.81	9.14	88	85.33	10.63
	3 hrs.				79.66	3.47
	5 hrs.				73.66	0.37
Beecher	Untreated	3.94	7.28	82	77.83	32.71
	3 hrs.				60.50	3.71
	5 hrs.				61.66	0.00
Spartan	Untreated	4.51	7.58	90	86.16	4.70[5]
	3 hrs.				75.33	0.78
	5 hrs.				69.83	0.00
		North Platte, Nebraska				
Atlas	Untreated	3.68	9.45	98	87.66	5.40
	3 hrs.				84.16	0.71
	5 hrs.				58.16	0.00
Feebar	Untreated	3.36	9.41	97	93.16	0.44
	3 hrs.				89.66	0.43
	5 hrs.				83.50	0.00
Flynn	Untreated	3.79	9.33	95	89.33	4.82
	3 hrs.				84.00	0.72
	5 hrs.				83.33	0.00
Beecher	Untreated	4.00	9.31	96	89.16	13.22
	3 hrs.				80.50	0.00
	5 hrs.				77.83	0.00
Spartan	Untreated	4.13	9.24	96	86.16	2.96
	3 hrs.				88.00	1.47
	5 hrs.				67.50	0.00

Table 9. (cont.).

Variety	Hot-water treatment	Wt. in grams of 100 seeds	Percent Moisture	Germination	Emergence	Smut
			Highmore, South Dakota			
Atlas	Untreated	3.80	9.14	95	86.16	7.84
	3 hrs.				83.33	0.61
	5 hrs.				81.00	0.00
Feebar	Untreated	3.53	9.53	99	94.16	2.15
	3 hrs.				90.00	0.28
	5 hrs.				92.00	0.00
Flynn	Untreated	3.94	9.20	96	92.00	5.00
	3 hrs.				87.33	0.60
	5 hrs.				87.66	0.00
Beecher	Untreated	4.30	8.90	91	88.83	17.81
	3 hrs.				86.16	1.04
	5 hrs.				77.33	0.00
Spartan	Untreated	4.04	9.08	93	90.66	1.82
	3 hrs.				87.66	0.38
	5 hrs.				81.50	0.00
			Dickinson, North Dakota			
Atlas	Untreated	3.50	8.69	84	83.33	5.17
	3 hrs.				82.50	0.45
	5 hrs.				56.16	0.00
Feebar	Untreated	3.62	8.90	98	92.00	8.76
	3 hrs.				90.50	3.37
	5 hrs.				87.83	0.00
Flynn	Untreated	3.70	8.78	98	93.33	1.40
	3 hrs.				86.16	0.31
	5 hrs.				89.00	0.24
Beecher	Untreated	4.15	8.92	98	93.00	5.53
	3 hrs.				84.16	0.47
	5 hrs.				67.83	0.00
Spartan	Untreated	4.21	8.79	95	89.33	3.64
	3 hrs.				81.33	2.83
	5 hrs.				67.00	0.00

Table 9. (cont.).

Variety	Hot-water treatment	Wt. in grams of 100 seeds	Percent Moisture	Germination	Emergence	Smut
			Akron, Colorado			
Atlas	Untreated	3.93	8.35	99	92.33	1.81
	3 hrs.				90.16	0.00
	5 hrs.				76.33	0.00
Feebar	Untreated	3.39	8.44	98	90.50	0.00
	3 hrs.				93.50	0.00
	5 hrs.				90.83	0.00
Flynn	Untreated	4.39	8.25	95	93.33	3.01
	3 hrs.				90.83	0.19
	5 hrs.				72.83	0.00
Beecher	Untreated	4.75	8.30	99	92.66	5.99
	3 hrs.				84.33	0.00
	5 hrs.				77.50	0.00
			Laramie, Wyoming			
Atlas	Untreated	4.30	9.41	98	92.50	2.59
	3 hrs.				86.33	0.00
	5 hrs.				46.33	0.00
Feebar	Untreated	4.08	9.22	98	95.16	2.52
	3 hrs.				90.83	1.54
	5 hrs.				90.50	0.00
Flynn	Untreated	4.55	9.11	86	91.00	2.27
	3 hrs.				90.50	0.94
	5 hrs.				85.33	0.00
Beecher	Untreated	4.91	9.24	98	92.66	9.11
	3 hrs.				85.20	0.38
	5 hrs.				67.66	0.00
Spartan	Untreated	4.04	9.27	93	93.16	3.66
	3 hrs.				91.33	1.07
	5 hrs.				74.16	0.00
			American Falls, Idaho			
Atlas	Untreated	4.05	9.60	94	88.83	0.00
	3 hrs.				87.33	0.00
	5 hrs.				70.83	0.00

Table 9. (cont.).

Variety	Hot-water treatment	Wt. in grams of 100 seeds	Percent Moisture	Germination	Emergence	Smut
Fesbar	Untreated	3.04	9.68	96	93.66	0.00
	3 hrs.				93.50	0.00
	5 hrs.				90.83	0.00
Flynn	Untreated	3.82	9.75	95	90.16	0.00
	3 hrs.				87.83	0.00
	5 hrs.				86.50	0.00
Beecher	Untreated	4.28	9.69	93	88.33	0.00
	3 hrs.				83.66	0.00
	5 hrs.				70.66	0.00
Spartan	Untreated	4.26	9.55	98	92.50	0.00
	3 hrs.				91.33	0.29
	5 hrs.				89.00	0.00
			Moccasin, Montana			
Atlas	Untreated	2.39	7.99	97	90.83	0.00
	3 hrs.				87.16	0.00
	5 hrs.				69.83	0.00
Fesbar	Untreated	2.40	8.48	98	94.83	0.00
	3 hrs.				87.50	0.00
	5 hrs.				84.50	0.00
Flynn	Untreated	2.46	8.14	97	90.83	0.00
	3 hrs.				85.83	0.00
	5 hrs.				78.16	0.00
Beecher	Untreated	2.94	7.95	98	92.16	0.17
	3 hrs.				86.66	0.00
	5 hrs.				63.16	0.00
Spartan	Untreated	2.56	8.45	95	86.33	0.00
	3 hrs.				73.66	0.00
	5 hrs.				65.50	0.00
			Moro, Oregon			
Atlas	Untreated	3.72	8.75	98	94.00	0.00
	3 hrs.				89.83	0.00
	5 hrs.				77.33	0.00

Table 9. (cont.).

Variety	Hot-water treatment	Wt. in grams of 100 seeds	Percent Moisture	Germination	Emergence	Smut
Feebar	Untreated	3.48	8.82	98	94.50	0.28
	3 hrs.				87.50	0.14
	5 hrs.				87.00	0.00
Flynn	Untreated	4.07	8.89	96	95.50	0.50
	3 hrs.				85.33	0.22
	5 hrs.				87.83	0.00
Beecher	Untreated	4.40	8.81	98	92.66	0.11
	3 hrs.				87.66	0.14
	5 hrs.				68.50	0.00
Spartan	Untreated	4.02	8.72	98	92.33	0.28
	3 hrs.				78.00	0.00
	5 hrs.				73.50	0.00
		Lind, Washington				
Atlas	Untreated	4.17	8.26	98	88.00	0.00
	3 hrs.				77.33	0.00
	5 hrs.				11.16	0.00
Feebar	Untreated	3.30	8.16	97	89.66	0.00
	3 hrs.				80.83	0.00
	5 hrs.				68.33	0.00
Flynn	Untreated	4.13	8.39	99	85.16	0.00
	3 hrs.				79.83	0.00
	5 hrs.				77.00	0.00
Beecher	Untreated	4.65	8.88	98	90.33	0.00
	3 hrs.				70.33	0.00
	5 hrs.				19.66	0.00
Spartan	Untreated	4.05	8.36	96	83.16	0.00
	3 hrs.				61.33	0.00
	5 hrs.				42.83	0.00
		Mean for all Stations				
Atlas	Untreated	3.74	8.78	94.83	88.17	3.87
	3 hrs.				83.81	0.52
	5 hrs.				62.97	0.00

Table 9. (concl.).

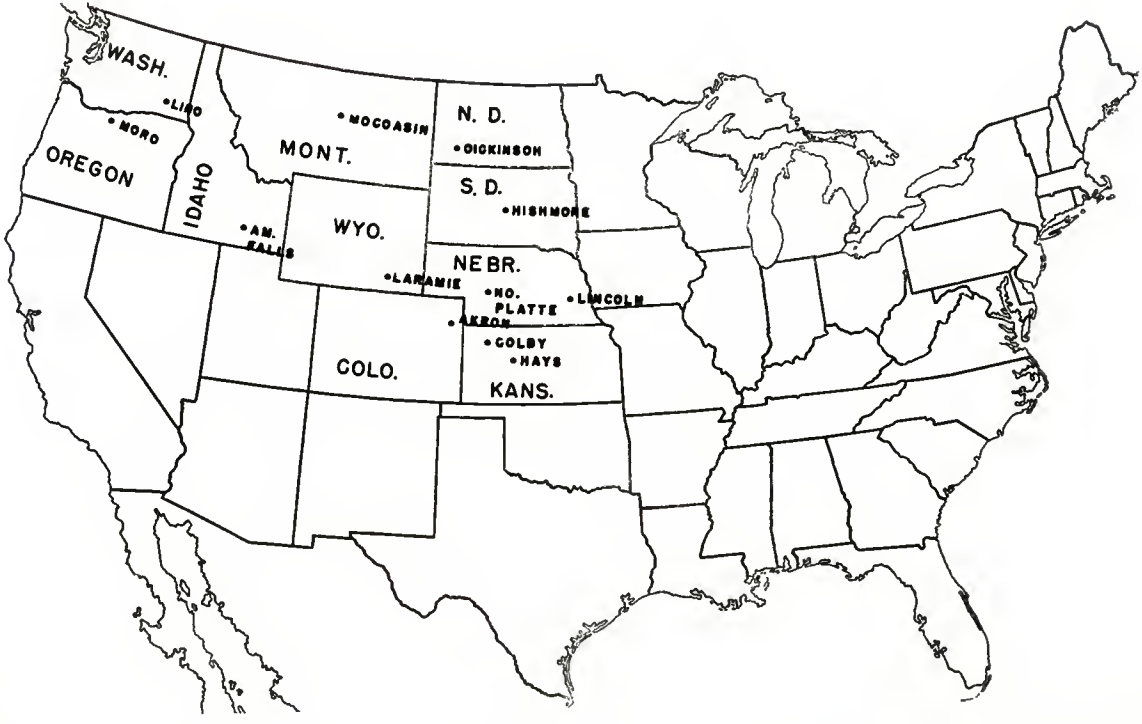
Variety	Hot-water treatment	Wt. in grams of 100 seeds	Percent			
			Moisture	Germination	Emergence	Smut
Feebar	Untreated	3.36	8.73	97.58	92.33	1.86
	3 hrs.				89.32	0.62
	5 hrs.				85.49	0.00
Flynn[6]	Untreated	3.85	8.87	94.36	90.70	3.09
	3 hrs.				85.89	0.78
	5 hrs.				82.24	0.06
Beecher	Untreated	4.18	8.72	95.92	89.50	10.06
	3 hrs.				82.57	0.75
	5 hrs.				81.49	0.00
Spartan[7]	Untreated	3.98	8.70	95.18	89.33	2.65
	3 hrs.				80.97	0.90
	5 hrs.				70.91	0.00

1 Four replications of 150 seeds each from 12 stations.
2 Moisture content determined at time of treatment.
3 Germination tests run by seed laboratory March 8, 1948.
4 Three-hour and five-hour prescaking followed by regular hot-water treatment.
5 Untreated Flynn, Hays, Kansas, also had .49 percent U. nigra; untreated Spartan, Colby, Kansas, also had .42 percent U. nigra; untreated Spartan, Lincoln, Nebraska, also had .52 percent U. hordei.
6 Eleven stations only, no Flynn from Colby, Kansas.
7 Eleven Stations only, no Spartan from Akron, Colorado.

EXPLANATION OF PLATE VII

Geographical locations of twelve experiment stations from which spring barley samples were received.

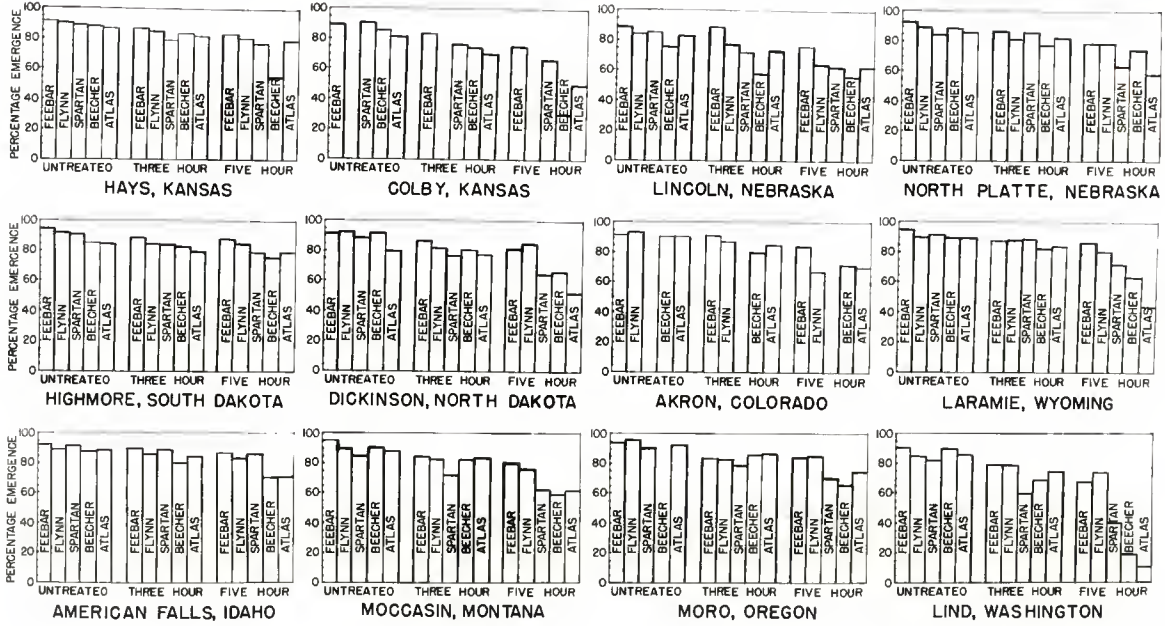
PLATE VII


WASH.
LIND
MORO
OREGON
IDAHO
MOCCASIN
MONT.
N. D.
DICKINSON
S. D.
HISHMORE
WYO.
AM. FALLS
LARAMIE
NEBR.
NO. PLATTE
LINCOLN
AKRON
COLBY
HAYS
COLO.
KANS.

EXPLANATION OF PLATE VIII

Percentage of emergence in five varieties of spring barley using untreated and hot-water treated samples from twelve stations. Three-hour and five-hour indicate length of prescaking periods preceding hot-water treatment.

PLATE VIII


PERCENTAGE EMERGENCE
UNTREATED
THREE HOUR
FIVE HOUR
FEEBAR
FLYNN
SPARTAN
BEECHER
ATLAS
HAYS, KANSAS
COLBY, KANSAS
LINCOLN, NEBRASKA
NORTH PLATTE, NEBRASKA
HIGHMORE, SOUTH DAKOTA
DICKINSON, NORTH DAKOTA
AKRON, COLORADO
LARAMIE, WYOMING
AMERICAN FALLS, IDAHO
MOCCASIN, MONTANA
MORO, OREGON
LIND, WASHINGTON

the same climates, had entirely different reactions. Examples of this were Moro, Oregon, contrasted with Lind, Washington, and Colby, Kansas, contrasted with Akron, Colorado. In support of the environment, there was a slight correlation in the reaction of the variety Beecher at Colby, and Hays, Kansas. Peobar was the variety least injured by the hot-water treatment.

Plate IX presents data on the percentage smut in samples from the 12 stations when the hot-water treatment had been employed. Beecher had the greatest smut infection. Samples of barley from Hays, Kansas, and Lincoln, Nebraska, had more smut than any of the other stations. None of the samples from Lind, Washington, contained any smut, and the samples from American Falls, Idaho; Moccasin, Montana; and Moro, Oregon, had but slight amounts of smut present. Flynn from Lincoln, Nebraska, was the only exception in which the five-hour presoaking period failed to completely destroy all the smut. There was a consistent decrease in the smut as the presoaking period was increased. Like the previously described hot-water treatment experiments, Beecher had more smut infection in the untreated samples, and was more severely injured by the maximum presoaking period. The environmental conditions seem to have had an important bearing on the amount of smut present as the stations that had the higher smut infections also had similar climatic conditions.

In the majority of cases the three-hour presoaking period gave good control. If the grower is producing a variety such as Beecher, any gain in reducing loss from smut by using longer than the three-hour presoaking period would be more than offset by the decrease in the germination with the more severe treatment. The data from these hot-water treatment

EXPLANATION OF PLATE IX

Percentage of Ustilago nuda in five varieties of spring barley using untreated and hot-water treated samples from twelve experiment stations. Three hour and five hour indicate length of presoaking periods preceding hot-water treatment.

PLATE IX

PERCENTAGE SMUT
0
10
20
30
40
UNTREATED
THREE HOUR
FIVE HOUR
BEECHER
FLYNN
ATLAS
SPARTAN
FEEBAR
HAYS, KANSAS
COLBY, KANSAS
LINCOLN, NEBRASKA
NORTH PLATTE, NEBRASKA
HIGHMORE, SOUTH DAKOTA
DICKINSON, NORTH DAKOTA
AKRON, COLORADO
LARAMIE, WYOMING
AMERICAN FALLS, IDAHO
MOCCASIN, MONTANA
MORO, OREGON
LIND, WASHINGTON

experiments all indicate that this treatment decreases germination, but with the five-hour presoaking period gives excellent control. Livingston (1947) obtained similar results. In addition to the injury caused to the barley in order to obtain satisfactory and adequate control, it is unfortunate that this is a rather impractical method for the farmer because he often would not have the facilities to properly conduct this type of treatment.

SUMMARY

Ustilago hordei can be distinguished from *U. nuda* and *U. nigra* by the presence of a heavy protective membrane covering the brownish black smut mass. Microscopically, this covered smut of barley has smooth spores which germinate by producing sporidia. *U. nigra* also produces sporidia upon germination but is not enclosed within a rigid protective membrane and its spores are echinulate. *U. nuda*, like *U. nigra*, is a loose powdery smut with echinulate spores but it does not produce sporidia upon germination, instead it germinates with the production of long threads of mycelium. The spores of *U. nuda* are lighter brown in color and have an olivaceous green appearance while those of *U. nigra* are brownish black in color. There is no definite method of differentiating the two loose smuts macroscopically.

Heads of *U. hordei* usually remain enclosed within the leaf sheaths and the peduncles are often twisted or kinked, while heads of the loose smuts emerge from the leaf sheaths and the peduncles show no twisted or kinked effect.

With the use of chemical seed treatments, Spergon gave no appreciable increase in percentage emergence of spring barley while New Improved Ceresan gave a definite increase in percentage emergence.

In the experiment dealing with farmers' samples of spring barley, there was but a small percentage of *U. hordei* and *U. nigra*. The predominate species of smut was *U. nuda*. There was no apparent significance in the distribution of the three species of barley smut over the state. The variety Beecher had the largest percentage of smut present but

apparently was resistant to or escaped U. hordei and U. nigra. The variety Trebi seemingly was resistant to or escaped all species of barley smut, while the variety Flynn seemed to be equally susceptible to all species.

With the use of hot-water treatments for the control of brown loose smut, there was considerable varietal variation as to the injury upon germination. Beecher was most severely injured with the five-hour presoaking period followed by the regular hot-water treatment, while Peebar was least injured. With but one exception, the five-hour presoaking followed by the hot-water treatment gave complete control of smut. There was no significant correlation between the weight of seeds, moisture content, or percentage germination preceding the treatment with the amount of injury inflicted on the various varieties, by the use of the hot-water treatment.

There was, apparently, a correlation between the environmental conditions and the amount of smut in untreated samples. The percentage of smut decreased as the period of presoaking preceding the hot-water treatment was increased. The three-hour presoaking period followed by the regular hot-water treatment did not give complete control, but in cases such as the variety Beecher, the gain in obtaining complete control by the use of the five-hour presoaking period followed by the hot-water treatment was more than offset by the decrease in germination resulting from the increased presoaking period.

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